JOURNAL

OF THE

AMERICAN PEAT SOCIETY

A QUARTERLY JOURNAL DEVOTED TO THE DIFFUSION OF KNOWLEDGE OF THE UTILIZATION OF PEAT, AND THE DEVELOPMENT OF AMERICAN PEAT RESOURCES.

Contents and Index

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JANUARY, 1920, TO OCTOBER, 1920.

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Contents and Index

VOLUME XIII.

JANUARY TO OCTOBER, 1920

REVUE de l'INGENIEUR et INDEX TECHNIQUE

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Each issue contains:—

(a) Extracts of original articles, referring to economical and technical subjects.

(b) A scientific and industrial chronicle, a chapter on economic information and a bibliography of works recently published.

(c) A technical Index, (a bibliographic and documentary list) classified according to the decimal system (Dewey system) rendering an account of the technical contents of the periodicals of the entire world.

The bibiliographic and reporting service of the Revue de l'Ingenieur is the same as that which furnishes the index on all technical subjects.

The Service is completed by a translation department.

Mr. Chas. Knap, Secretary,
American Peat Society,
Whitehall Building,
New York, City.

Dear Sir:—

I, the undersigned, being interested in the development of our peat resources and in the welfare of the peat Society, beg to make application to membership in your Society, for which I enclose $5.00 as annual dues.

Signed ....

Address ....

....

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Journal of the
American Peat Society

Vol. XIII JANUARY, 1920 No. 1

NOTE.

The publication of articles in the Journal of the American Peat Society is not an endorsement of the same by the Society or its officers. The American Peat Society is not responsible for the statements and opinions advanced by authors or correspondents. Written discussions on articles appearing in the Journal are invited. Correspondence and articles regarding peat and cognate subjects solicited.

SECRETARY-TREASURERSHIP.

Commenting on the appointment of Mr. Chas. Knap to the Secretary-Treasurership of our Society (see this Journal, Volume 11, page 35), your editor assured you that this appointment would not be regretted. In looking over the books of our Society we were so impressed with the correctness of this prophecy, that we include below a table showing the Financial Result of Operation of our Society since its inception.

It will be remembered that Mr. Knap took office during December, 1917, and the effect of his administration can be clearly seen from the table presented below.

The average member of any Society rarely recognizes the importance of the Secretaryship, and the large amount of work and mental strain the same incurs. Our present Secretary is certainly a great credit to our Society, and the work he has accomplished since he entered office is highly commendable to him, and he deserves the sincerest congratulation of our membership.

Results of Operation.

September, 1907, to July, 1919.

	Receipts	Expenses	Yearly Cash Balances
Sept., 1907, to Oct., 1908	$ 238.00	$ 195.01	$ 42.99
Oct., 1908, to Oct., 1909 (1*)	314.00	323.15	33.84
Oct., 1909, to July, 1910 (2*)	243.24	264.26	12.82
July, 1910, to July, 1911 (2*)	887.14	754.18	145.78
July, 1911, to July, 1912	549.00	621.29	73.49
July, 1912, to July, 1913 (3*)	863.98	864.30	73.17
July, 1913, to July, 1914 (4*)	570.12	570.12	73.17
July, 1914, to July, 1915 (5*)	595.99	629.91	39.25
July, 1915, to July, 1916 (6*)	836.67	870.98	4.94
July, 1916, to July, 1917 (7*)	532.20	500.51	36.63
July, 1917, to July, 1918	824.50	612.40	248.73
July, 1918, to July, 1919	885.09	743.46	390.36
	$7,339.93	$6,949.57	
	6,949.57		
	$ 390.36		

(1*) Includes Loan of $100.
(2*) Includes Subscription from Canadian Gov., $400.
(3*) Includes Loan of $200.
(4*) Includes Loan of $100.
(5*) Includes Loan of $150.
(6*) Includes Loan and Contributions, $422.
(7*) Includes Loan of $157.63.

(Signed) CHAS. KNAP,

Nov. 28th, 1919. Treasurer.

PEAT AND U. S. GEOLOGICAL SURVEY

The influence which the Government Departments can be in promoting a healthy industrial and agricultural development of the peat resources of our country was clearly seen during the time of our late Editor, Prof. Chas. A. Davis.

Prof. Davis had a hard road to travel on entering this field, and practically assisted the Society in stamping out and minimizing the fake promotion for the development of peat, then existing. He assisted us in creating greater confidence in the development of peat and brought about the recognition of peat as one of our natural resources.

Since quite some time the U. S. Geological Survey has had Mr. Osbon in charge of their Peat Department. Mr. Osbon is known to our readers, but his greatest achievement in peat is still to come. We do not refer to the article on "Peat in the Dismal Swamp" which is reprinted in this issue, but to a work on the "Occurence and Uses of Peat in the U. S.," which we understand will probably be the largest and most comprehensive work on this subject that has yet been issued in this country. Prof. E. K. Soper is a joint author of this report.

The report of "Peat in the Dismal Swamp" is, to our mind, one of the masterpieces of peat literature, and Mr. Osbon is to be highly congratulated in the care and thoroughness with which this report has been prepared.

The country was indeed fortunate in having Mr. Osbon in charge of its peat work and it is with extreme regret that we have to report his resignation, as Mr. Osbon has taken up work, outside of the Government Service, which holds out to him greater financial returns for the efforts and application of his knowledge.

It is so common today that the best minds in Government employment are taken away from the service of the country, that we wonder whether Congress will ever wake up to the fact that the higher costs have come to stay, and apply not only to the public-at-large, but also to those in the Government service. It is also high time that our Government recognizes that brains are also becoming more valuable and that the future development of this or any other country depends on the development of its brains as much or more than its muscle.

Despite the fact that our members will be sorry to see Mr. Osbon step out of the peat field, yet we wish him all the success and lucrative benefits which his new work can shower on him, and want him to know that he will always be a welcome guest in our circles. HERBERT PHILIPP.

BACTERIZED PEAT IN ENGLAND.

Now that the strain of the Great War is gradually passing over, we understand that new experiments are being conducted in England with bacterized peat.

Information has reached us that results are proving satisfactory and we presume soon that more details of the work carried on will be available.

The full activities of bacteria in plant life, in fact in our general existence, is only in its infancy, and during the next decades the part that bacteria plays in our evolution will become more apparent.

Those of us who have only scratched this subject realize the importance that bacteria play in plant life, and some have become so enthused as to indicate that all the chemical reactions taking place are activated by bacteria. Only the future can determine the actual role played by these organisms.

HERBERT PHILIPP.

OBITUARY.

Josiah Quincy of Boston, a member of our Society of long standing, died on Sept. 8, 1919.

A. Stamford White of Chicago, Ill., a member of the Society, passed away during the month of December, 1919.

GENERAL CONSIDERATIONS OF PEAT PROBLEMS.*

By Peter Christianson,**

School of Mines, University of Minnesota.

In opening this meeting I am conscious of the fact that we are living in very extraordinary times, and that conferences were never more important. These meetings, conferences, conventions, or whatever we wish to call them, tend to enlarge our horizons, to give us a bird's eye view which enables us to correlate facts and thus obtain the true significance of these extraordinary conditions.

The general tendency is to increase the prices of everything. This is particularly true of fuel and land, and when the prices of fuel and land are advanced, the foundation of every field of activity is changed.

There are doubtless many reasons for this advance in prices, but there seems to be two which stand out in bold relief. These are first an abundance of money or medium of exchange, and second, decreased production or increased demand. These are fundamental reasons and can be traced through the entire net work of commercial activity. The first, viz., an abundance of the medium of exchange, is not within our scope of consideration, but the second brings us face to face with our peat problems.

Peat is valuable for two purposes, viz., fuel and agriculture. To the extent that peat is used as a fuel and to the extent that peat land is used for agriculture, our fuel supply and our agricultural areas will be increased. Hence the utilization of peat both for fuel and agricultural purposes will tend to increase production and to stabilize prices by an increased production.

There is no question as to the fuel and power value of peat. There is no question as to the agricultural value of peat lands. These values have been established and it is only a matter of working out the details of utilization. This working out details constitutes our peat problems and the American Peat Society is vitally interested.

These problems are pressing for solution, first, on account of the present increased demand, and second, on account of the vast area and the vast amount of material involved.

As an example, take the State of Minnesota. The estimated original swamp areas in this state is 10,000 square miles. Of

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*Read at the Annual Meeting, Minneapolis, Minn., Sept. 22, 1919.

**President of the Society.

this the swamp area containing peat is estimated at 7,000 square miles; and 5,000 square miles of this vast area is estimated to contain peat of sufficient depth to be valuable for fuel. In order to get a more concrete idea of this area let us convert square miles into townships, each six miles square and each containing thirty-six square miles. The 7,000 square miles of peat area in this state available for agricultural purposes is equal to about 200 townships, of which 5,000 square miles, or about 150 townships, are available for fuel purposes.

When it is realized that each township contains 23,040 acres and that all of this land is geographically located where the rainfall is sufficient to insure certainty of crops, the importance of our peat area becomes apparent. Again, when it is realized that twenty acres of peat land containing a peat deposit five feet in depth will yield sufficient fuel to run a 2,000-kilowatt power plant for one year, and that one square mile at this rate will supply fuel for such a plant for 30 years, the importance of peat as a source of power becomes apparent.

These considerations taken in connection with the increasing demands for land to raise food and clothing, the increased cost of fuel both for domestic and power purposes, the importance of our peat problems becomes still more apparent.

Again when we consider the vast waste of lumber which has taken place right in the same area where the peat bogs occur, we are brought face to face with another phase of our peat problems. Peat, like our forests, forms one of our natural resources, and, like forests, peat may be destroyed by fire. This brings us to another consideration, viz., that of conservation. Peat should be utilized but not wasted.

The pine forests of Northern Minnesota, Wisconsin, and Michigan could have been made a perennial source of valuable lumber had due care been exercised to save the young trees from destruction. As it is, our forests have been destroyed and the lumber we now use must be transported half way across the continent, at an increased cost to consumers. This unnecessary cost of transportation of large quantities of material due to ignorance of the value of our natural resources and carelessness in utilizing same, is a phase of this problem which should be emphasized.

Conservation should be the watchword. In our eagerness to utilize, due care should be exercised and no wasteful and destructive methods used.

Drainage of peat land is necessary for utilization, but drainage should be regulated, and the bogs should not be drained for any considerable length of time before they are

utilized. Under no circumstances should bogs be drained below the point necessary to produce crops. A peat bog drained dry is a constant fire hazard, and aside from the waste of material, a dry peat bog on fire is a very difficult proposition to handle.

In order to avoid the waste which has attended our lumbering operations, some comprehensive scheme looking toward a systematic development of our practically unsettled areas in which peat lands predominate, some area of sufficient size should be carefully selected and studied with special reference to both agricultural and marketing conditions. When these considerations have been worked out, special inducements to settlers should be offered in this particular area. In other words, concentrate development to a certain definite area. This will tend to minimize privations to settlers and losses of peat by fire.

Finally, a practical and economical method of handling peat, both for fuel and power purposes, should be developed. To the extent that this is perfected the transportation cost of fuel will decrease and the northwest will become independent of eastern coal and transportation companies.

Summary.

First. The American Peat Society should serve the purpose of disseminating peat information. In these meetings, exchange of ideas and correlation of work going on in the various parts of the country can be accomplished.

Second. Peat and peat lands are valuable both for agricultural and industrial purposes.

Third. Working out the details of utilizing peat lands for agricultural and peat for fuel purposes constitutes the peat problems.

Fourth. The increasing demand for agricultural lands and the vast areas of peat lands available, together with the increasing prices of fuel and agricultural products, serve to emphasize the importance of peat problems.

Fifth. Conservation is the watchword and systematic development should be the program.

CO-OPERATION IN PEAT INVESTIGATIONS.*

By R. W. Thatcher,

Dean of the Department of Agriculture and Director of Agricultural Experiment Stations, University of Minnesota.

As many of you know, I came into my present administrative position after having served for a number of years in a department of agricultural chemistry at University Farm. In my former position, I was interested in many problems of the development of Minnesota's agricultural resources from the standpoint of scientific possibilities and aspects. Since I have come into the administrative work, my contact with these problems has been more from the standpoint of organization and administration of this development work. In this connection, I have had occasion to attend numerous conferences and conventions of various associations, committees, etc., which are concerned with the development of the natural resources of the state.

The outstanding impression which I have received from these conferences is the amazing and disconcerting lack of correlation and co-ordination or even of sympathetic mutual understanding between the various agencies which are working with the same general purpose and toward the same general end. For example, during one week recently I attended four different conferences, all having for their purpose the better and sounder development of the peat lands of northern Minnesota. No one of these bodies had any knowledge of or apparent interest in the activities of any other one. When I mentioned to one of the groups, consisting mostly of civil engineers, the fact that other groups were interested in this same problem and that co-operation in plans and efforts was desirable, the presiding officer called my attention to the fact that this particular group was not concerned with the real estate promotion side of the problem or with the agricultural utilization of these lands but was dealing with the engineering possibilities in the situation, particularly as to flood control and water power.

I think that it is obvious that this state of affairs is not the most promising one for the success of any general constructive plan, which must be based upon public interest in and support of the movement.

In the first place, this unfortunate lack of co-operation fails to bring to the support of the movement any large pro-

*Read at the Annual Meeting, Minneapolis, Minn., Sept. 22, 1919.

portion of the general citizenship of the state, such as is necessary if the movement is to grip the public mind and receive general public support. The lack of any united public support of or demand for constructive plans for development of the state's natural resources is particularly noticeable at times when the state legislature is in session, when all sorts of plans and schemes are presented but none of them with any united pressure of public opinion back of them. The result is that legislative support is easily split up into ineffective conflicting groups by scheming politicians or by selfish financial interests which still desire to exploit these natural resources for their own private gain rather than for public good.

But there is a still more unfortunate effect of this lack of co-operation. I allude now to the effect upon public opinion of the common habit of criticism by one group of the plans or motives of another group which is working upon some other phase of the same problem. I believe that this condition is largely responsible for the lack of confidence in the value of so-called "expert" advice which the great mass of our people have. It is possible to get experts to testify on opposite sides of almost any question in which scientific principles are involved. These apparent conflicts in authoritative statements based on technical considerations which the ordinary layman cannot understand often lead juries in court cases to disregard altogether the testimony of the so-called "opinion witnesses" and to base their findings upon the direct or circumstantial evidence of lay witnesses. A similar effect is easily to be seen in the general public reaction toward propositions put forward by groups of experts, namely, that of a scornful indifference or of actual suspicion as to the motives which are back of the proposition. And I am bound to say that there would seem to be some justification for this attitude on the part of the public.

Take, for example, the public utterances of groups of scientific men on this question of utilization of peat. One group, composed of fuel engineers and interested in the possibility of utilizing peat as a source of heat energy, openly and publicly derides the possibility of the reclamation of peat lands for agricultural uses, and advertises that it is developing a process which will make it possible to convert all the peat of the state into commercial fuel and speculates upon the enormous profit which will accrue to the state if its experiments are successful. Another group makes public its opinion that all these attempts at utilizing peat for fuel are foredoomed to failure and that experiments are under way to show how peat lands of different types can be drained and made over into successful farms. A third group publicly and officially condemns

the draining of peat lands as creating fire menace. And so it goes.

It seems to me that the time has come when some agency ought to undertake the task of organizing co-operation between the various groups which are interesting themselves in development work in Minnesota. I notice that the American Peat Society has enlarged its interests to include all possible phases of peat utilization. Is it not possible for a Minnesota section of this society to undertake to bring together into some harmonious working organization, the various groups of scientists who are conducting peat investigations of various kinds, so that each may understand what the others are doing, and that conflicting opinions may be ironed out in conference, to the end that the general public may be correctly informed as to the needs and possibilities of this work and may understand that scientific investigators are really seeking to promote a constructive plan of development of the state's resources rather than to conduct campaigns of jealous controversies or of personal attacks upon each other?

That co-operation among investigators having a different background or fields of scientific training, but an interest in some common general problem, can be successfully secured is shown by recent experiences in our Department of Agriculture at University Farm. We organized first the Animal Industry Group and more recently a Plant Science Seminar, both of which bring together for purposes of conference and constructive criticism of each other's work, the scientific men of our staff who have a common interest in the general field represented by the title of the group. These men and women are now meeting in general discussion groups and I believe that I do not overstate the facts when I say that there has never been such a hearty spirit of co-operative work and of united effort in the solution of research problems on our campus as exists now.

I believe that the American Peat Society can make a real contribution to the successful solution of the many problems in connection with the best utilization of the great peat deposits of America, if it will efficiently support a movement for close co-operation of the various groups and types of scientific workers who are now interested in the several different phases of this general problem.

AGRICULTURAL VALUE OF INDIANA PEAT AND NECESSARY FERTILIZERS.*

By S. D. Conner,

Purdue University Agricultural Experiment Station, Lafayette, Indiana.

Indiana contains several hundred thousand acres of peat and muck soils. Some of these soils are composed of a fairly pure grade of peat, others, which were originally peat, are now more or less disintegrated and mixed with clay and sand and are more truly termed muck. Practically all these soils are locally called muck.

Types of Peat.

From a crop standpoint there are two general classes of peat soils in Indiana: First, those well supplied with lime; and second, those deficient in lime. There are, of course, all gradations of peat between those containing marl or shells, and those which are extremely acid.

The type of peat well supplied with lime is as a rule the most valuable agriculturally, because it is not so costly to make productive. Quite often acid peat is found that will require as much as twenty tons of calcium carbonate per acre to grow corn.

Over nine-tenths of all the muck soil in Indiana is found in the three tiers of counties along the northern boundary of the state. There are, however, a few isolated bodies of muck in the central and southwestern counties.

Drainage of Peat.

The first step in the reclamation of peat is proper drainage. To be properly drained it is almost as important that these lands are not made too dry as it is to remove the excess water. Thirty inches to fifty inches from the surface is a very satisfactory level to hold the water table. In 1904, in Newton County, over 60 bushels of corn per acre were grown on peat soil with a water table at no time over twenty-five inches from the surface. On the other hand, on peat which has been very deeply drained the crops were a total failure because the land cracked open and dried down to a depth of several feet.

Drained peat may be destroyed by fire if carelessly handled. Peat will burn down to water and it is very difficult to extinguish burning peat except by digging a ditch around the fire down to water.

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*Read at the Annual Meeting, Minneapolis, Minn., Sept. 22, 1919.

In ditching peat soil a drain should be extended around the side of the tract next to high land so as to cut off the excess water which may run down upon it. Springs due to underground veins should be tapped and drained out.

Peat soil which is cultivated has a tendency to decay quite rapidly and in this way the surface is slowly being lowered. In some instances this lowering of the surface takes place to such a degree that the soil again becomes too wet and new drainage must be installed.

Frost Damage on Peat.

In northern Indiana crops are quite liable to be injured by frost in either the spring or fall and sometimes even in midsummer. Cold air has a tendency to flow into the lower levels where muck is usually found and as a consequence crops are often killed on muck when they are not injured on other types of soil. This condition is without doubt partly due to the physical nature of the soil as well as to the low level of the land.

Early maturing varieties or hardy crops should always be grown on peat. Blue grass pasture is often the most profitable crop to grow on peat which is very susceptible to frost.

Non-acid Peat.

Probably four-fifths of the peat and muck of Indiana is of the sweet or non-acid type. As a rule this type of peat is mainly deficient in potash and in a much less degree in phosphate. It is not in need of lime or nitrogen, although in some cases available nitrogen will produce a profit on very early sown crops such as onions.

Much of this sweet peat in Indiana is so well supplied with available nitrogen and the conditions which are favorable to nitrification are so perfect (such as aeration, lime, and nitrified organic matter), that nitrates accumulate to such an extent on the surface that young onion plants are killed.

Samples of peat soil taken in July in Noble County contained 0.50% NO_3 in the surface soil where onions were dying and 0.17% NO_3 where the onions were good. Again, in Starke County in September, onions failed with 0.34% NO_3 and did well where only 0.10% NO_3 was found in the soil surface. Such damage is considered due more to high concentration of soluble salts, principally nitrates, rather than to poisonous action of the salts. When the accumulation of total salts reaches 0.50% in the surface layer of soil there is danger of injury both to corn as well as onions. This type of injury is more liable to occur on deeply drained than on shallow drained

peat. It takes place only after a period of hot, dry weather. Cool, rainy weather prevents it, both by stopping excessive nitrification and by leaching and distributing the soluble salts into the subsoil.

With average or good weather conditions and proper fertilization and soil preparation, sweet peat is highly productive. Table I gives some crop yields with and without potash fertilization on this type of soil.

Table I.—Some Crop Yields on Drained Sweet Muck or Peat, Largely from Purdue Bulletin 157.

County	Year	Crop	Yield, bu. per acre No fertilizer	Yield, bu. per acre Best fertilizer
Newton	1906	Corn	35	74
Madison	1905	Corn	75	92
Starke	1906	Corn	13	70
Henry	1907	Corn	23	53
Benton	1905	Onions	607	731
Whitley	1907	Onions	307	547
Kosciusko	1908	Onions	628	703
Noble	1909	Onions	394	483
Noble	1909	Onions	372	551
Starke	1906	Potatoes	63	198
Starke	1907	Potatoes	155	309
Tippecanoe	1910	Potatoes	141	171
Porter	1919	Oats	40	......
Porter	1919	Rye	28	......

Acid Peaty Soils.

The acid type of peaty soil, when very acid, must be limed and treated with phosphate. Potash is a minor need. One very acid Indiana peat tested by the Veitch lime water soil acidity method showed a carbonate of lime requirement of fifty tons per acre to neutralize all the acidity. Although it is not necessary to neutralize all the acidity of peat soil to grow crops, it is often necessary to apply excessive and probably unprofitable quantities of lime before satisfactory results are obtained. This particular soil grew corn with 16 tons limestone per acre and none with 8 tons per acre. Still another acid peat tested grew crops with 20 tons limestone per acre and none with 12 tons.

These very acid soils may be distinguished in the field by the vegetation upon them. Huckleberries are often found

on marshes where the peat is very acid. Blue grass is never found upon acid peat while sweet peat will run to blue grass if drained and pastured.

Some moderately acid peat can be cropped with little or no lime if properly fertilized otherwise. Such a peat soil tested by Purdue in Jasper County showed an average increase of over 20 bushel of corn per acre where phosphate was used and no increase with potash or lime.

Some slightly acid peat, muck and peaty sand soils will respond more to potash than to phosphate. Some such soils require both potash and phosphate. The phosphate in such instances seems to be needed to hasten the start and the maturity of crops.

How to Classify Peat.

Corn is the most sensitive towards deficiency of potash of any crop grown on peat soils. Hence when a blue grass peat is cropped to corn, without fertilizer or manure, and the corn dwindles and turns yellow when two to four feet high, or even makes fair early growth but matures only chaffy grain, it is known that potash is the element needed. Muck is found of all grades of natural productivity. Some will grow ten to twenty good crops and others will fail to produce at all without fertilizer.

In addition to the action of the crops and natural vegetation as a means of classifying peat and muck agriculturally, some simple laboratory tests may be made. Of these laboratory tests the ammonia test is the easiest. The most acid peats tested in Indiana are over fifty per cent. soluble in ammonia water, while peat or muck sweet enough to contain fragments of shells or marl, gives a perfectly white and clear solution with ammonia.

It takes quite a little experience to enable a chemist to classify peat soils by means of chemical tests alone. The various methods of testing soil acidity give quite different results. For this reason experience in the field must be correlated with laboratory experience..

As a rule the sweet peats and muck are apt to be black while the acid types are more frequently brown in color. The degree of decomposition, however, modifies the color to some extent independently of acidity, the undecomposed soils being more brown than those which have disintegrated.

Summary.

1. Indiana contains several hundred thousand acres of peat and muck soils.

2. If properly drained and fertilized these soils are ca-

pable of producing large and profitable crops.

3. Peat and muck must not be drained too deeply for best results.

4. From an agricultural standpoint peat may be classified as neutral and acid.

5. The neutral peats are the most prevalent in Indiana. They respond almost always to potash fertilization.

6. The acid peats are in need of lime and phosphate more than potash.

7. Over 90 bushels of corn, 700 bushels of onions, and 300 bushels of potatoes per acre have been grown on experimental plots on peat soil in Indiana.

8. The vegetation naturally growing upon peat is a certain indication of its type.

9. Laboratory tests will indicate the type of peat soil and the probable fertilizer needs.

THE IMPROVEMENT OF WILD MEADOW AND TULE LAND.*

By W. L. Powers,

Oregon Agricultural College, Experiment Station.

General Description of the Region.

Few definite data have been obtainable regarding the duty of water or improvement of swamp land and wild hay meadows. These lands embrace several million acres in the intermountain great basin region. More than one-third of the irrigated land in Oregon is wild meadow. There are perhaps more than 350,000 acres of wild hay meadows alone, and including the marsh or tule land, approximately half a million acres in Central Oregon is mainly producing native grasses for pasture and hay or is idle tule land. Much of this land is fertile and capable of great increase in productiveness through control of the water and seeding of more valuable forage crops; whereas the present practice tends to drown out the most valuable grasses.

The chief areas of our wild meadow lands occur in large depressions in the great lakes district, south central Oregon. These depressions were caused either by faulting or by lava flows which interrupted the natural drainage, giving rise to a marshy condition. The average elevation of these lands is 4,000 feet above sea level and the growing season is therefore short, ranging from three to five months for hardy plants and ten weeks to four months for ordinary crops. The average precipitation is about twelve inches. The meadows are watered largely from the melting snows in the mountains. There is a flood season and a season of low water. A system of wild flooding has been practiced for distributing the water over the wild hay meadows. This primitive method of irrigation has been persisted in throughout much of the area, largely due to the lack of transportation, large holdings of land, application of abnormally large amounts of water, and the desire to maintain a low cost of production. Improvements of these lands will necessitate levees or outlet drainage ditches in places and better storage and control of the irrigation water so that it can be applied in periods. This will make it possible to replace the wild grasses with more digestible, higher yielding, domesticated clovers and grasses, and it will afford a means of controlling the alkali.

*Read at the Annual Meeting, Minneapolis, Minn., Sept. 22, 1919.

Vegetation.

The chief vegetation of the peat marshes or lower acres is tules and flags mingled with wire grass and sedges, the latter (chiefly Carex aquatilis), is locally called "sugar grass." On the margins of the low marshes on medium peat and peaty loam rice grass and wire grass intermingle with tuleage and flags in low spots. On the wild hay meadows which are largely silt loam the vegetation is chiefly red top, blue joint, wire grass, timothy, wild millet and wild clover. On sub-irrigated areas the vegetation is chiefly blue point, blue grass, and timothy. Still above the sub-irrigated areas on the hummocks are patches of salt grass, and clumps of "grease wood" (atriplex) lands occur on the low benches and on the valley floors in most of these lake basins. Outside of these are great areas of summer range land. The wild hay meadows are used pasture or are cut for winter feeding of the range stock.

Soils.

Peat and silt loam are the two exclusive soil types found in the wild meadow country. Much of the peat is of medium depth and underlaid with silty diatmaceous material which is rather chalky when dry. Below this chalky layer, at a depth of five or six feet, the soil is usually a medium sandy loam. Areas of deep peat occur in the lower parts of these marshes toward the open water. At slightly higher elevations the peat layer becomes thin and an intermediate belt of peaty loam or muck soil occurs, extending more or less continuously around the outer edge of the peat. The medium and deeper areas of peat soil show an acid reaction. The peat marshes are more or less circular and in some cases partly surrounded by a clay or mud flats interspersed with the peaty loam soil.

Typical silt loam in the wild meadows is a dark, deep soil, usually with a slight slope and somewhat better aerated than the marsh land proper. This type of soil is frequently formed as deltas of streams entering marshes and is traversed by meandering sloughs with willows along the banks. Where drainage is fairly good the wild grasses and clovers form natural meadows on the land. making a fairly good quality of hay, much better than the sedges which abound on the medium peat. This dark silt loam occurs in most of the valley floors in Eastern Oregon and probably throughout the inter-mountain region. Its composition has been found fairly uniform even in widely separated districts of Oregon and it forms one of the most desirable soil types in these marsh or swamp areas.

Fringing the silt loam an area of very fine sandy loam with so wind formed hummocks and a clay loam subsoil, is frequently encountered, which is alkali in its character. Salt grass and grease wood occur in these marshes of flats which are above the food plain of the meadows and are not flushed by annual flooding. Alkali from nearby land is apt to be drawn up and accumulated on the higher spots or marsh rims, and it also is increased by the perculation of water coming from higher slopes to the drainage basin. Where deep outlets are close at hand drainage and copious irrigation will reclaim all but the worst of these areas. In some cases, however, the areas are so flat, alkaline, and sticky that reclamation at present is not feasible.

Sage brush land above and surrounding the areas already described usually have good drainage. Where a good growth of sage brush occurs the soil is usually a fine, sandy loam and is desirable for irrigation. Better control of the water on the marshes will make it possible to reclaim large areas of these outlying, low, bench lands and greatly aid the development of the region in general.

Mechanical and chemical analysis from different marshes show that these dark silt loam soils are uniform in texture and of good fertility. Their usual water capacity is nearly two acre inches per acre foot under field conditions, while for the peat it is nearly twice as great. In some cases the per cent of phosphorus is rather below average. Fertilizer trials conducted the past four seasons on three different marshes do not show a profitable increase from the application of either phosphorus or potash. Lime has benefited Alsike clover on these lands but has aggravated the alkaline conditions due to an increase in carbonate. The clay loam on the marsh rims has responded markedly to application of elemental sulphur where crops such as alfalfa have been grown. There are some indications that potash will help on the deep peat and that phosphorus will need to be supplied in the long run on the soils of wild meadow area.

Irrigation.

The flood water is spread out over these marsh lands by wild flooding from canals led along the contour lines. The slough banks also are frequently higher than the surrounding land, so that the water can be distributed from the sloughs by the use of dams and head gates. During the flood season the water table is raised to the surface and sheet water extends over large areas. In some places drainage canals are later provided to remove the greater part of the excess and permit drying out of the land for winter pasture. Few levees or

ditches control the water, and thousands of acres are irrigated in some cases from one outlet. Measurements and statements the farmers made during the past four years show the average yield of native grasses on the wild meadows will not exceed three-quarters of a ton native hay an acre. Where the flood water can be controlled it is believed the strip border method of irrigation will be suitable for large parts of this wild meadow land. It has been tried with success on meadows under investigation. With this method the water can be more evenly applied in periods and the soil permitted to warm up and aerate between applications.

Drainage.

Drainage usually precedes irrigation on the tule lands. A drainage canal about sixty feet wide and twenty-five miles long has been constructed in Blitzen Valley. In Chewaukan marsh a drainage canal of similar length has been made. In the Klamath Basin the construction of levees along the lakes or Klamath River has been the first step toward reclamation. In some cases channels have been built to conduct inflowing streams across the marsh to the open water of the lake. In Klamath Basin during the year 1917 the storm water was pumped out from two dyke areas of several hundred acres each at the beginning of the season. Irrigation water was pumped on later in the season. This water was measured and analyzed and an appreciable amount of alkali was removed by this process. Peat lands are protected from excess moisture readily under the climatic conditions and an extensive system of interior field drainage is not required. Under some conditions an open ditch every five hundred feet may be desirable.

As the peat decays, ditching at more frequent intervals may come to be profitable. Good crops are being raised on marshes up to one thousand acres in area where only a center drainage ditch is provided, leading the surface water left from winter precipitation to a pumping plant, where when necessary is lifted over the dyke. On the wild meadows better control of irrigation is the first step in improvement. Along the tule marshes drainage is of first importance.

Subduing the Land.

Following drainage, the rank mass of tules can be removed by burning off when dry; the soil below is still moist enough so as not to be burnt out. Burning off the tules provides a little plant food and tends to overcome any rawness or sourness of the soil. It must be carefully done to avoid injury. The first year the plowing should be of only moderate

depth. The furrows should be turned over almost flat to aid decay. A wide plow and the caterpillar tractor has been used with success on these lands. A corrugated roller has been found valuable for firming these marsh soils to secure good germination.

Choice of Crops.

Oats for hay will usually be the first crop, or oats and field peas may be grown one or two years to subdue the soil before seeding down to meadow. These crops yield three or four tons an acre. A permanent meadow mixture successfully used and recommended is alsike and timothy. It is not difficult to establish where a firm, well-prepared seed bed is provided, and where good inoculated seed is used. This crop yields on an average about three tons of hay an acre and affords additional late pasture. On low-lying meadows unsuitable for clover, red top and timothy can be harrowed in and established without plowing up. Some improvement can be had in this way until better drainage and control of water can be provided. On the best quality of wild meadows some clover has been established together with timothy by seeding down timothy and clover hay on the land. The best wild meadow should be the last ones to be plowed up and reseeded, as they are fair producers not so badly in need of leveling. Clover will remain on the meadow more permanently where the water table is kept down below the level of the bulk of the root system. Capillary action of much of this peat soil tends to bring moisture to the surface at a distance of 24 to 30 inches above the water table under field conditions. The water table should be at a distance of at least 2 feet below the surface during most of the growing season. This water should not be stagnant. With good drainage and control of irrigation, alfalfa can be grown on much of this area. Every few years the meadow should be renewed or renovated, so something of a rotation should be practiced. Some small grain should be grown each year for seed where the climate permits a reasonable chance of it maturing. Rye or sweet clover will help loosen up the alkaline sub-surface strata, in the margin of the marshes, and afford some pasture during reclamation. Copious irrigation and deep drainage will keep the alkali moving down and out in affected under drainage areas. Sweet clover and rye are crops that can be used to advantage on such alkaline land during reclamation. To establish sweet clover successfully, we have found that it is necessary to use good scarified seed and a firm seed bed to keep the soil moist until the young plants are established. After the crop shades the

ground the sweet clover is fairly resistant to alkali. It will help to loosen up the land and facilitate reclamation.

Irrigation Requirements to Wild Hay Meadows and Tule Lands.

Experiment fields have been maintained in three marsh areas in south Central Oregon, and for the past four years water variation trials have been conducted under field conditions and checked by the use of large soil tanks arranged to show the most economical yield per unit water and the maximum yield per unit land. The results show that an average depth of 18 inches of water on the field could produce maximum yields at present secured, or a little more than the most profitable yields of hay crops on the marsh lands. The greatest yield of wild hay per acre inch has been secured frequently with a net use of 12 inches depth of water per acre. The yield per acre inch becomes more important where water is limited and the land area available if irrigation is in excess of the water supply. In such cases it is more important to use tame grasses which require less water per pound of dry matter produced. A small portion of these wild meadow lands can be cultivated, using hardy grain crops and row crops with some rotation and an occasional loosening up of the soil to give a better distribution and more efficient use of the water. The quantity of flood water pumped from two dyked tracts in Klamath ranged from none to 3½ acre inch an acre, while the quantity pumped on for irrigation later in the season ranged from 6 to 12 acre inches. From the quantities pumped on and off these dyked marsh areas and containing several hundred acres in each case and fairly free from sub-irrigation, it would seem that where some excess water is to be drawn off at the beginning of the drawing season, leaving the soil in a very moist condition, it would not be necessary to apply more than 12 acre inches per acre as supplemental irrigation later on in the season. Under this condition a pumping plant serves a dual purpose. Some alkali is removed in this irrigation and the drainage process. The supplemental irrigation late in the season provides a favorable moisture condition for the feeding roots in the surface soil layers where the most available plant food is to be found and forces growth during the best growing weather. It also serves to some extent as a protection against fire on the peat marshes in extremely dry seasons and keeps any alkali salts distributed through the soil.

The average water cost per pound of dry matter for alsike and timothy grown on these meadows under good conditions averaged about 600 pounds per pound of dry matter, while for native or wild grasses it runs from 1,000 pounds per pound dry matter, upward. The average yield of wild hay is about

¾ of a ton an acre, whereas the alsike and timothy has averaged about three tons an acre, or has given twice the yield with about half the water commonly used on the wild hay land. In the Klamath region, about 5,000 acres of wild meadow lands have been converted to alsike and timothy and are producing twice as much forage and of a higher quality than was formerly secured.

Advantages of Development.

The time seems ripe for converting large portions of these wild hay meadows to tame clover and grass lands. It is believed that these lands will pay a better rate of interest on the total investment over large portions of these areas where the water can be controlled so the tame grasses can be grown. In other words, the net profit over the cost of production under normal conditions would represent interest on a valuation of perhaps $30 to $50 per acre; good clover and timothy meadows should pay a similar rate of interest on a valuation of $65 to $90 an acre.

Modern agriculture contemplates the use of well-bred domesticated plants. It is fundamental that something of a rotation be practiced in the growing of legumes crops with the application of barnyard manure in rotation. Even on fairly permanent meadows, the clovers will help to keep the land loosened up and offset the tendency of the water to crack the soil. The roots of these legumes add nitrogen to the soil beside increasing the valuable protein substances in the forage.

The wise system of irrigation contemplates applying soil water moisture when the supply for the crop is down near the wilting point in just sufficient amount to raise it to the excess point throughout the soil strata within the reach of plant roots. Under proper irrigation, little or no moisture should escape over the surface or below the reach of roots to contribute to the formation of a high water table. While a little loss may be allowable under present economic conditions, still these are the standards for modern irrigation to work toward if the highest development and the most profitable system of irrigation agriculture is to be reached and maintained. Moisture should be kept moving down by the intermittant irrigation and cultivation whenever necessary. The fact that dry farmed lands do not "go to alkali" if not so affected in the initial state shows that with proper control of moisture soluble salts in soil can be kept distributed or removed. Drainage is the real remedy in such cases of excess alkali in these meadow lands. The feeding experiments of our branch experiment stations also show that the marsh grasses are higher in crude fiber and

lower in digestibility than the tame grasses and legumes. It is believed that the control of water and the establishment of domesticated crops will double the productiveness in large parts of our several million acres of meadow lands in the mountain country and great basin region, and this will permit saving water to be applied to fertile adjacent bench land.

There is in Western Oregon peat lands similar to those in the Central States. These are partly reclaimed and devoted to intensive truck. There is another class of marsh lands, including our tide lands, along the coast. Their improvement is discussed in Oregon Experiment Station Bulletin No. 157.

VEGETABLE GARDENING ON EASTERN MUCK SOIL.*

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Sixty-five years ago the production of vegetables was a small industry of purely local significance carried on in the immediate vicinity of the cities where the products were consumed. About that time a shipload of produce was consigned from Norfolk to New York, and so Southern trucking had its beginning. Some twenty years later the invention of the refrigerator car widened the field, both for production and for consumption. It was not for long that the current flowed exclusively northward and before many years the south was enjoying in the winter months the potatoes, cabbage and other vegetables which its hot summers forbade its producing for itself. But this is not all. Today the current of produce-laden cars flows in all directions, carrying to each city not only the things which it cannot grow for itself, but also the things which can be grown more cheaply or better elsewhere. Even hothouse lettuce goes from Toledo southward as far as Chattanooga at the same time that the Florida outdoor product is sold in Toledo.

The vegetable industry is involved with some forty or more crops of commercial importance, each characterized by an insistence, more or less rigid, upon a set of conditions which favor its growth. Thus are they set apart from the great staples which thrive in one form or another from Texas to Minnesota and from California to New England. Some vegetables demand a long season, others high humidity, others cool nights, others a hot summer, and so on. Nearly every crop has been tried under nearly every type of conditions, each neighborhood proving all things and holding fast that which is good.

In this half unconscious quest for the best place to grow each crop, the muck lands of the country have not been overlooked. They have proved to be preeminently adapted for the production of onions, celery and summer lettuce, and they are well suited for several others.

Confining our attention to the muck lands of the glaciated portion of our country, we find them scattered in areas large and small thruout Northern New Jersey, Northern Pennsylvania, New York, Michigan, and the northern parts of Ohio, Indiana and Illinois. Such lands are to be found in Wisconsin and Minnesota, but they have been but little developed for vegetable production. Among the large areas are Great Meadows,

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New Jersey; Orange County and Canastota, New York; Kenton, Ohio; the Kankakee Swamp of Indiana, and the areas about Kalamazoo, Michigan. There are many others. At the same time a large share of the production is on small areas from one to a few hundred acres, scattered far and wide among the states mentioned. The Lake Ontario counties of New York are marked by this type of development, Fulton and Williamson being important centers.

The growing of muckland products is a highly specialized branch of agriculture. A working knowledge of ordinary farming is by no means sufficient to insure success. Unless the beginner has had opportunity to study the methods of successful producers he will find it best to begin on a small scale and gradually learn the tricks of the trade. Muckland gardening has appealed strongly to promoters of corporation farming. Failure has been more common than success, often on account of the difficulty of securing experienced men to handle the practical operations in the field. Nor does a high degree of success in a small enterprise insure ability to manage a large operation.

The labor demands of all muckland crops are heavy; especially is this the case with onions. In consequence the weeding, cultivating and topping have fallen largely to foreigners. In some places employment is on a time basis, in others on an acre basis, and in still others on a share basis. The workers are usually thrifty, and after a time they seek leases of land, build shacks to live in, during the summer at least, and after a while they have gained title to holdings that are worth several hundred dollars an acre. This situation is well illustrated at Canastota, New York, and the foreigners have proved most substantial members of the community, strongly supporting co-operative movements, educating their children and in general making good Americans of themselves.

The essential equipment for muckland gardening does not involve a very heavy outlay. A living is frequently gained from the cultivation of five acres, and for this a single horse, a small wagon, a few tools and a shed of second-hand lumber are about all that is required. At the same time as a man's business develops, the building of greenhouses, and the purchase of such special equipment as celery blanching boards, onion crates and toppers, and the like, maintain the average at a fairly high figure per acre. This, however, should be viewed in the light of the large crop values that are involved. A survey of the South Lima area made some nine years ago indicated an average investment in buildings and equipment aside from homes of $2,890 per holding averaging about 11 acres

each. At the same time three owners operated five to six acres each with an average investment in equipment of about three hundred dollars. Of course values are higher now.

Land values for muck that is suitable for vegetable crops vary widely. Distance from railroad, difficulty of drainage, cost of clearing, and other factors render some areas practically worthless. Uncleared but perfectly good blocks may be bought at figures in the neighborhood of a hundred dollars per acre, while holdings that have been in successful operation and that are favorably located have changed hands at from five to six hundred dollars. In the years before the war new clearings were constantly being made and the total area was increasing materially. At the same time values were decreasing in some localities. In fact, there is quite a tendency toward fluctuation. Let the main ditch get into bad shape and let a few bad seasons follow one another, and purchases can be made at low figures. Put the drainage in good shape and let success crown the efforts of the growers and they turn down good offers. Muckland enthusiasm seems to migrate from center to center much as baseball fever follows the winning teams. Wayne and Oswego counties in New York have been recent foci of infection. Every farmer who could find a plot of black soil was developing it and those who had none were buying.

There is still room for marked expansion in muckland vegetable production. The wonderfully delicious head lettuce that these lands afford is not enjoyed nearly as widely as it should be, and precooling has made satisfactory transportation possible. Celery has developed from Thanksgiving garnish until it is one of the great vegetable crops. The muckers have made it hard for city market gardeners, whose costs are materially higher, tho they have the advantage in quality. The storage and shipment of celery have been materially improved. Consumption of these two vegetables has never been encouraged in the way that Western fruits have been pushed. At the same time the amount of available land suitable for development is such that there is no occasion for pushing operations into localities that can be improved only at high cost or that are not well served by transportation facilities. It must be remembered that an acre of muck may readily yield a carload, while it takes fifteen acres to make a car of hay, and fifty or more for a car of grain.

The marketing problems of the muckland trucker are much more complex and difficult than those of the ordinary farmer or of the city market gardener. He deals with highly perishable products, which, with the exception of onions, are

anything but staple, and he is usually far from his market—or rather markets. At say South Lima, New York, cars may be seen loading side by side for Baltimore and Kansas City, for Pittsburg and Minneapolis. Growers must watch many markets and must face a succession of gluts and shortages on each. He must know his consignees and must be able to command service from railroads and dealers.

Sales may be made to local buyers, to transient buyers, to commission merchants, or by small shipments to grocers and jobbing houses in many small centers. The complex problems of harvesting, packages and packing, hauling and loading must be solved for both economy and effectiveness. The mucker must be a good business man.

In considering the industry as it has developed on the mucklands, let us first take up the conditions that they offer for vegetable production. The glaciated region of our country is well to the north, and so we deal with cool climates. The location of these lands in low places serves to accentuate this condition as does the high water holding capacity of the soil which makes them slow to warm up in the spring. Thus they are not at all fitted for early crops and no effort is made to compete with upland gardeners who have all the advantages of warm site and soil. Nor are they fitted to crops that require a very long growing season.

The muck soils where gardening flourishes represents the well decomposed peats and in general show low percentages of mineral admixture. They are very light in weight, thoroly friable, and may be cultivated with the lightest tools and with little effort. While, as indicated a moment ago, they hold water with great tenacity, they drain rather slowly and movement of moisture from water table to surface is very slow. They are by no means immune from drouth, plants frequently suffering when within four feet of the level of ground water.

Swamps that have been covered with deciduous growth—ash, elm and soft maple—and which represent the decomposition of such trees, make better vegetable soils than those which have been covered with the conifers, as white cedar and tamarack. The latter are usually less thoroly broken down. Their resinous constituents may be a factor in this. Such soils are usually lighter, more flaky and brownish rather than black in color. They are more subject to drouth and they seem otherwise to be somewhat less productive.

Adequate drainage is essential to successful muckland gardening. There must first be the possibility of a suitable outlet. Some areas are entirely surrounded by much higher ground so that drainage is not feasible. In other cases a very

long canal would be required, while in still others the water level of a lake or river interferes. The drainage of small muck areas can often be controlled by the owner and may be comparatively simple. With the larger areas, where there are many holdings, the problem is often greatly complicated, calling for the highest engineering and legal skill coupled with a practical knowledge of the objects to be attained and a willingness on the part of the owners to co-operate in the enterprise. State drainage laws are various and devious and contractors are too often greedy or inefficient with the result that costs have in many cases been unduly high, and results unsatisfactory. South Lima and Arkport, New York, have had their troubles and Canastota was forced to go to the legislature for special enactments.

With the main ditches provided, it is usually possible to proceed with clearing. Some cut the trees and afterward dynamite or pull the stumps. Others upset the trees before cutting, using caterpillar tractors. Each block offers its own problems which must be worked out according to circumstances. The leveling of land involves much labor and is of prime importance, as slight depressions are sometimes markedly unproductive. At best the settling process will require some years. Burning of the surface offers no advantages and there is grave danger of starting fires that will do great damage. Considerable care must be exercised in burning the slashings after clearing. It does not require a very large fire to make a hole that will be an obstacle for years.

With clearing accomplished and the main ditches in working order, drainage of the fields remains to be provided for. Open laterals are best for the first few years and on some farms they are retained permanently. Such ditches are, however, highly objectionable on account of the waste of land the interference with tillage operations and hauling, the harboring and scattering of weeds, and the labor of keeping them open in a soil that is markedly unstable. Some growers partially solve the weed problem by maintaining smooth, slanting sides instead of the sod-capped, vertical sides. One method is about as troublesome as the other. The use of tile has proved perfectly feasible, even where the fall must be very slight. The lines must be laid with great care, usually on boards to insure good alignment. The joints may be protected with bits of paper to prevent the influx of muck until the soil has settled about the tile. Settling basins at the junctions of lines and traps to prevent backflow are commonly introduced as needed.

While muck soils are very light and friable, their tillage is not without its difficulties. Ordinary plows are generally

used, but considerable care must be exercised to secure a model that will actually turn a furrow and not merely drag thru the soil. Nor is there an agreement as to the kinds that will meet this requirement. In fact, it seems to vary with different areas. The share must be kept absolutely free of rust. Otherwise a bit of muck adheres and starts an accumulation that will speedily cover the whole share and prevent its scouring. The operator must study his own soil to determine the stage of moisture at which it works best. Some have had excellent success with plows of the disc type. Rollers, light or heavy, and plank drags and scrapers are of great value for leveling and firming the seed bed. A very loose condition prevents the transmission of moisture from below and also manifests itself in an uneven growth of the crop. Ordinary spring and spike tooth harrows are employed, and the Acme and Meeker are excellent for finishing. In many cases the last step in preparation for the seed drill is to give a final leveling with a plank drag.

Most of the muckland products of the country are grown without the aid of irrigation. Even tho these lands lie low and the water table is near the surface and the upper three feet of soil may contain enough moisture for two or three crops in ordinary soil, yet the plants often suffer for lack of water. While most growers cultivate faithfully and then accept losses from this cause, hoping for more rain next year, there are many who have made provision for the control of the water level. Ordinarily small streams flow into the swamps from the adjoining upland and dams may be used to raise the water level in the drainage ditches. A grower near Batavia, New York, is so situated and he has been able to give transplanted celery a favorable start by soaking the soil thoroly for several days, then allowing it to drain out previous to setting. At the same time his neighbors had the joy of watching their plants turn yellow and stand still till rain came. Another successful grower finds a complete overhead system of irrigation with a deep well and pumping plant a profitable investment in connection with his thirty-acre garden.

Definite systems of rotation are not commonly practiced in muckland gardening. In fact, some communities have been able to grow the same crop on the same land thru a long series of years without apparent harm. In most cases, however, time has shown the advantages of a more varied scheme. Considerations of disease, insect and weed control, of distribution of labor and income, and of insurance against failure of a single crop, all point to the wisdom of a diversified plan. Seldom is a season unfavorable thruout and seldom do all crops suffer dis-

aster. Onions require the whole season, while two crops of celery or lettuce may be produced in a summer. Onions ordinarily leave the ground quite weedy and a planting of early celery the next year gives opportunity to subdue them. This may be followed by late lettuce with early lettuce the next spring. A crop of late celery to be earth blanched leaves the ground very clean for the succeeding crop of onions. Such a plan is not often rigidly followed, but it serves to illustrate the factors involved. Some planters who serve a trade of large grocers and small wholesale houses try for a succession of celery and lettuce from July to frost, tho occasional breaks are unavoidable. Weather conditions sometimes bring three sowings of lettuce made at ten-day intervals to maturity practically together.

A number of experiments of an empirical nature have been made for the purpose of pointing out the best practice in the feeding of muckland crops. The usefulness of the results has been limited in many cases by faulty planning, by lack of repetition, and by the fact that the soils of different swamps respond differently. Accordingly we know little of a fundamental nature regarding the fertilization of vegetables on these lands. When potash was abundant a mixture carrying about four per cent of nitrogen, in both mineral and organic forms, eight per cent of phosphate and ten per cent of potash was widely employed, many making applications as heavy as a ton per acre. Tho the soil itself may contain as much nitrogen as some low grade fertilizers, it is in relatively unavailable form, and the heavy additions of this element were found to give unprofitable returns, even on areas that have been long cultivated and are presumably well aerated and inoculated. Many other combinations were in uses and practices, varied widely as to time of application. Lettuce has been found to do well on the residues remaining after the heavy treatments for celery and onions. Stable manure is prized but seldom available in quantity. Reports as to the value of lime vary, but in most cases the soils used for vegetable production are already basic and applications are not commonly made.

Time will serve merely for the briefest review of the problems involved in the production of each of the leading muckland crops. It will be recognized that the practices indicated are merely representative and that the widest variations prevail.

The onion takes its place by the side of the potato and cabbage as one of the great staple vegetable crops which are stored in quantity for use thruout the winter and are heavily used in all parts of the country. Tho the Connecticut valley

with its alluvial soil is an important factor, the bulk of the crop for fall and winter use is produced on the mucklands of New York, Ohio, Michigan and Indiana.

Onion seed is planted by means of ordinary man power seed drills such as are found in all commercial gardens. The soil must be very even and the machine must be carefully adjusted and closely watched to insure proper distribution of seed, as thinning is very laborious and little practiced. With rows fourteen inches apart, a common spacing, four to six pounds of seed per acre are required. Devices are often attached to drills for the application of a mixture of ury lime and sulphur or of a formalin solution in the row with the seed for the prevention of injury by onion smut (Urocystis cepulae).

If the muck is dry at seeding time, the crop is at once subjected to its first danger. A wind sweeping across the field will very speedily blow out the seed that has just been planted. Hedges are used for windbreaks, tho they waste both moisture and land. Some use portable fences woven with wire and lath. Overhead irrigation has been used to excellent advantage.

Weeds come up as soon as the onions, and for several weeks the battle rages between the grower and his enemies. Much tedious hand work is involved. Weeders with fingers revolving at right angles to the row have been employed with considerable success. The cultivation of the soil between the rows is accomplished by means of various sorts of wheelhoes.

As the crop matures the tops die down to the ground and the plants are then pulled and laid in windrows to dry and cure. If topping is to be by hand they are left so until they are fairly dry. Then tops are removed and the bulbs are placed in bushel crates, which are stacked in the field for further curing. They may later be hauled to cribs similar to corn cribs, where they can be held until hard freezing takes place. This plan has, however, given way to the use of frost-proof store houses, where they may be kept thruout the winter. When topped by machine they are usually placed in crates and cured fairly completely before this process.

The onion is somewhat at the mercy of the weather during the last weeks of its history. Rainy weather during its late growth results in "thick necks" or scullions which do not cure properly and are of poor market and keeping quality. Rainy weather after pulling results in discoloration and poor keeping.

Yields ordinarily range from 300 to 600 bushels per acre.

Celery without doubt ranks second in importance among the muckland vegetable crops. It is matured from the middle of July until late fall and may be kept by trenching or by cold

storage far into the winter. It is more perishable and somewhat more precarious than onions.

Seed for the early crop is sowed in greenhouses and for the late crop in outdoor seed beds. Golden Self-Blanching is by a wide margin the leading variety. Formerly only French seed was regarded as reliable, but of late years a few careful growers in California have been able to develop excellent stocks. The celery seedling is small and delicate, so it must be handled with great care. An over supply of moisture must be avoided to insure a well developed root system, so that transplanting may be safely accomplished.

The spacing of celery plants varies widely. Earth-blanching requires wider distances than the other methods. Plants are from four to six inches apart in single or double rows, and the space between rows varies from eighteen to thirty-six inches.

The blanching of the summer crop is an expensive process. For this purpose, twelve-inch boards may be held in place on each side of the rows by means of wire spanners. Or roofing of the rubberoid type cut into twelve-inch strips for the purpose may be supported by wire arches set over the row and into the soil. The late crop is blanched by banking with earth. However, the tendency is to let the late plants go into storage relatively unblanched and let the hearts come up afterward. Most celery is in any case very severely trimmed before it is sold.

Celery is sold "rough," that is as it comes from the field, or "washed," that is trimmed and scrubbed ready for sale to the consumer. The latter plan is appropriate if the product is to be promptly used, but the former plan is better if it has far to go or must be held for any considerable length of time. The outer leaves protect and preserve the hearts and when it reaches its destination it mav be trimmed out and washed so that it will appear in fine shape. Rough celery is generally packed in crates from 22 to 24 inches in cubic dimensions. Careful studies made by Prof. H. C. Thompson, then of the United States Department of Agriculture, now of Cornell University, have showed that crates but 14 inches wide are to be preferred both for transportation and storage, serving to minimize loss by decay.

A hundred and twenty-five to a hundred and fifty crates is regarded as a good acre yield.

There are few places in the United States where good head lettuce can be grown on upland soils in midsummer. The crop does well on muck soils, producing great solid heads of marvelous delicacy. At the same time it is very much of a gam-

ble. A crop may be nearing maturity in fine shape and an insidious tip burn, apparently in consequence of hot sunshine following rain, invades the head and mars every leaf from circumference to center. For causes that are obscure it may fail to head. Leaf rots may ruin a piece in the course of a few days. Then markets are fickle and easily glutted and many a carload has been a complete loss. At the same time if the grower "hits it right" he may net as much as a thousand dollars clear per acre. Year in and year out, however, the crop is sufficiently profitable that growers continue to plant it along with others. In fact some confine their attention to lettuce almost exclusively.

The leading variety is Big Boston, and seed is usually sowed in rows about fourteen inches apart at the rate of one to two pounds per acre. Plants are thinned to about twelve inches in the row. When the heads have formed they are cut and the better grades are usually packed in crates or boxes about 8 by 16 by 20 inches inside dimensions. These hold two to three dozen heads, packed in two layers, face to face. The lower grades are shipped in bushel hampers. Refrigeration shipment is necessary, and precooling by keeping for a few days in a cold storage warehouse has proved highly profitable. Six hundred boxes is regarded as a good acre yield.

Time fails for a fuller discussion of these crops or of the root crops, and of spinach for the cannery, and of potatoes for seed. Muckland gardening has by no means attained to its possibilities and it offers a most promising field for development. New areas are to be sought out and brought into cultivation, new markets are to be found and old ones cultivated. Scientific problems without number have been uncovered and remain to be solved. Muck soils are well nigh as various as upland soils and our knowledge of them will not be on a sound basis until we have found bases for classifcation and comparison. Surveys of the areas are needed, taking account of origin, composition, and present vegetation as well as other characters. The behavior of these soils under cropping serves to show us how slender is our knowledge of the conditions that prevail in the soil and of the influence of these conditions upon plants. We know almost nothing of the microbiology of peat and muck soils and of the physiological character of the solutions that are there present. While the fundamental truths are being worked out, we stand in need of vegetation experiments that will point the way to improved methods of production.

For the solution of some of these problems, we stand in need of a well developed muckland experiment station. It

should be located within easy reach of several types of these soils and several types of utilization. It should employ a well-trained scientific staff, which should consist of at least of a soils man, a chemist, a plant physiologist and botanist, with a crop specialist. The need for an insect man and a disease man would very soon be felt.

Thus whatever be our inclination, whether toward the scientific, the agricultural or the commercial side of muckland gardening, the field is wide and the way is open.

LOGICAL METHODS OF UTILIZATION OF MINNESOTA PEAT.*

By Henry H. Hindshaw,

Mining Engineer, Hibbing, Minn.

Minnesota is pre-eminently the great peat state. There is not only more peat than in any other state, but there is also a greater need of it.

Minnesota is a great fertile country with the kind of climate best suited to man's energies; his requirements in the shape of food, clothing and shelter are great and the means of supplying his necessities are abundant.

A large proportion of these materials is fuel for heating, cooking and manufacturing. It exists in great abundance in the form of peat. According to Professor Soper, there is in the state 6,800,000,000 tons of available peat, equal in heating value to five billion tons of anthracite, and of still greater value for the production of chemicals and oils for fertilizers and the raw materials for manufacturers and use in the arts.

Minnesota's unequalled riches in iron ore, its central location and waterways to the Gulf and Atlantic, its great areas of land that can be brought up to and maintained in a high condition of permanent fertility by the use of the nitrogenous fertilizers available on the development of peat, predestine it to be the manufacturing center of the United States.

Absolutely nothing has been done with this peat. Practically nothing has been done in the rest of the country. The time has now arrived at which we must avail ourselves of these resources. Conditions as to the production and transportation of coal have undergone great changes and enough success has been attained in the use of peat in European countries to make its successful utilization easily attainable. The great amount of experimental work and the number of failures on attempts to use it in a small way as a substitute for coal have not only served to demonstrate what can be done, but also showed us what to avoid.

Many various methods have been suggested and tried out for utilizing peat. Most of these can be included under the five following heads:

(1) Air dried peat, as cut turf for direct firing, or harrowed and collected on the surface of the bog and briquetted either with or without additional artificial drying, or burned in roughly powdered form.

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*Read at the Annual Meeting, Minneapolis, Minn., Sept. 24, 1919.

(2) Machined peat in brick form, burned as a coal substitute or as powdered fuel.

(3) Machined peat as gas producer fuel, without by-product saving.

(4) Machined peat in by-product saving producer.

(5) Machined peat in standard by-product ovens.

The first two methods are wasteful and except in the form of finely powdered, or atomized fuel, are only useable on a small scale under exceptionally rare conditions.

Cut peat, as it is still used in parts of Ireland, Russia and Germany, is a persisting relic of the Stone Age.

Machined peat has little to recommend it, as it is a low grade fuel intended as a substitute for coal. Its preparation in a marketable form on a large scale is impracticable and its bulkiness does not admit of its transportation by rail. Its use destroys its chemical value, which it intolerable without modern understanding of conservation. Millions of dollars have been spent over a period of fifty years on attempts to use peat in this without any good results.

Hundreds of patents have been issued, mostly on fragile mechanical contraptions intended to help out some particular stage of its manufacture.

Nearly all of our peat literature is devoted to machined peat. Professor Davis, in Bulletin 16 of the U. S. Bureau of Mines, gives quite a lot of information as to the botany and distribution of peat beds, but his work consisted mostly of warning people against doing anything as foolish as trying to make peat fuel. Canada has done better by publishing accounts of better methods in use in Europe.

The same experiments have been tried over and over again with the same failures. The impracticability of drying peat by mechanical means has been repeatedly demonstrated. Wet carbonization, which seemed to promise so much a few years ago, has failed to give any results.

The conception that a successful operation can be made to pay on a small scale, using the little German or Swedish pug mills of the Schlickheisen type, is about as logical as supposing that a coal mine equipped with a hand windlass could be made to pay.

There is only one form of direct fired machined peat which has anything to recommend it. As powdered fuel it has the advantage of not having to be finished in physical form to suit people who are used to shoveling coal onto a fire. It has the same advantage that powdered coal has over lumps, that is, that when either material is reduced to a powder that will pass

through a 200-mesh seive, it can be burned with the minimum amount of air.

This is the first form of peat entitled to enter the high grade fuel class, as it is superior to coal. The theoretical air required to supply oxygen for the combustion of a pound of coal is over 10 pounds, while a pound of peat requires only 7 pounds of air.

Peat powder burns more slowly than coal and the fire can be directly applied over a larger heating surface. Also, as far as I have been able to ascertain by experiments, peat powder is non-explosive.

Fine grinding of loose peat is almost impossible, but machined peat is the most easily powdered material that I ever put through a mill.

Under the third heading, machined peat as gas producer fuel without by-product saving, we are still using only half the value of the peat.

There is little information available, but that producers have been in operation over 15 years without reporting any trouble is enough to prove the practical success of their operation. Peat does not form coke, so the constant stirring necessary with soft coal is obviated. The ash will not slag or clinker so that it is easily removed and has considerable value as a fertilizer. The tar is said to be not as troublesome as from soft coal. The gas has a higher B. T. U. content than from anthracite or coke. For this purpose the peat can be finished in a granular or broken form and need not be as dry as that required for fine grinding. This seems to be the best method of using peat for small installations.

By-Product Saving Producer Gas.

The producer gasifies the whole fuel, fixed carbon as well as volatile. It is lean, as compared with retort gas, 140 B. T. U. to the cubic foot, and is preferable for many purposes to richer gas. There is some heat lost in the conversion from the solid to the gaseous fuel, but this is more than compensated for in the facility and economy of its burning.

The Mond type of producer is used for this purpose. The process is designed to keep down the temperature low enough to allow the nitrogen of the fuel to combine with hydrogen and form ammonia which can readily be saved in the form of sulphate.

It is practicable to recover about 70 per cent of the nitrogen of the fuel, amounting to about 70 pounds of sulphate of ammonia to a ton of peat for each 1 per cent of nitrogen contained.

Sulphate of ammonia is a staple article of commerce which can never be produced fast enough to fill the demand. The price has steadily advanced for many years and has now reached 5 cents a pound by the carload.

The average nitrogen of Minnesota peats is over 2½ per cent, so there is saveable 175 pounds to the short ton of peat gasified, with a market value of $8.75.

The gas, after deducting that required in the process of manufacture, amounts to 67,000 cubic feet per ton, 9,380,000 B. t. u.—enough to generate by gas engines, 938 horse power hours. Sold as gas for heating pnrposes at 5 cents per 1,000 cubic feet, it would equal a high grade coal at $7.35 a ton. At these prices a ton of peat would sell for $12.10. Assuming cost of dry peat at $3.00 and manufacture of sulphate at $20.00 per ton—$4.77, leaving a profit of $7.33 per ton of peat. One great advantage of this process is that the peat can be fed to the producer containing 30 per cent of moisture.

The most desirable operation is to sell the gas direct, distributing by pipe line to users. Where the plant is remote from a considerable market for heat, the gas would be used to generate power and transmit by electricity. This method has long since passed the experimental stage and has been in use in Italy and Germany.

B. F. Haanel, in a publication of the Canadian Department of Mines, No. 299, 1914, describes the process very thoroughly and gives estimates of the cost of plant in Canada. The process to be carried on as a commercial success must be on a large scale. A plant using 100 tons of dry peat a day, with a power production of 4,000 horse power, is the cost convenient unit. This would cost, on a rough estimate, one million dollars and would, with a 2½ per cent nitrogen content in the peat, produce 26,000 tons of sulphate and 4,000 continuous horse power.

By-Product Oven.

The best method of utilizing Minnesota peat is by means of the standard by-product oven. This was tried out in an Otto-Hoffman oven in 1904. No difficulties presented themselves which could not be easily overcome.

The ratio of fixed carbon to volatile combustibles in coal is approximately 2 of fixed carbon to 1 of volatile. In peat the ratio is reversed, 2 of volatile to 1 of fixed carbon. In the coke oven, with coke at $5.00 per ton, the coke has a value of $3.25 per ton of coal. The by-products, tar, benzol, solvent naptha, napthaline and sulphate of ammonia, $6.30 per ton of coal.

Using peat, the charcoal replacing the coke would be one-half the weight of coke, but its higher value gives the same amount, \$3.25. Assuming that the by-products of peat have the same value as from coal, there will be double the quantity and be worth \$12.60 per ton of peat, with a total of \$15.85 per ton of peat.

By-product gas has approximately four times the value of Mond gas and at 20 cents per thousand would be equivalent to coal at \$8.30 per ton.

The by-products oven treatment of peat would admit of the smelting of iron ores on the Messabi Range and by the almost unlimited possibilities of power production the immense deposits of magnetic iron ore could be profitably mined and concentrated and used in the production of low phosphorus charcoal pig iron of great value.

The blast furnace is a gas producer incidentally making iron, but it can only be successfully operated on a moderately large scale.

A furnace stack producing 100 tons of iron per day is as small a unit as could be considered. This would require 250 to 300 tons of peat per day. Its products would be pig iron and gas. The gas from 100 tons of charcoal would contain 2,500,000,000 B. T. U. Assuming that half of it would be available for gas engine use it would generate 125,000 horsepower.

Such a combined operation would be: Plant to produce 600 tons dry peat per day, six months' operation. By-product ovens, 300 tons of peat per day.

Saleable products:

100	tons charcoal at \$10 per ton	\$1,000.00	
2,400	gals. tar at 10c	240.00	
460	gals. benzol at 25c	115.00	
5,000	lbs. sulphate of ammonia at 5c	250.00	
660	gals. naphtha at 20c	132.00	
1,000	lbs. naphthaline at 6c	60.00	
2,000,000,000	cu. ft. gas at 20c per 1,000	400.00	
	Total		\$2,197.00

The blast furnace products would be:

100	tons of pig iron at \$30	\$3,000.00	
100,000	horsepower at ½c per h. p. hour	1,200.00	
			4,200.00
	Total gross income per day		\$6,397.00

This is the climactic form of peat utilization. There are a great number of minor uses which I should like to speak of, especially with regard to the use of the binding properties of peat. Peat, properly degasified by machining or especially machining in a vacuum, becomes without any mechanical compression as hard and dense a material as hard wood on drying. When once dry, it is not wetable. It is an ideal binder for iron ore fines or flue dust, but in spite of this fact, many attempts have been made to destroy this property by carbonization and briquetting the residue with a tar or oil binder.

As to its agricultural value. By applying sufficient industry and fertilizer, crops can be grown on peat, or rather, some crops can be grown in some climates. In Minnesota, Michigan and Wisconsin, we have miles of jack pine land which can be worked to better advantage and raise big crops by the application of fertilizers produced from peat. One acre of peat, one foot deep, can be made to produce 16 to 18 tons of sulphate of ammonia, enough to double the production of potatoes on a good sized farm for a generation.

Summarising the value of peat per ton, under these various methods:

Cut peat has no commercial value.

Machined peat blocks, or briquettes, with coal at $10 per ton	$ 7.50 per ton
Machined peat, finely ground (atomized)	15.00 per ton
Producer gas, without by-products	10.00 per ton
Mond gas and by-products	12.10 per ton
By-product oven gas and products	15.80 per ton

The whole scheme of peat utilization depends on two factors: its cheap production at the bog in usable shape, and in a transportable form.

We must at once dismiss the thought of the small unit peat plant which has vainly promised success for so many years. We are constantly told by wiseacres that "we must creep before we walk." We have done all the creeping necessary and now the big plants are merely a question of engineering and capital.

The many peculiarities of peat with which most of you are more or less familiar, are not all bad features, but they must be taken advantage of. They cannot be ignored. The peat engineer must profit by the failures that others have made or he will have to learn peat through failures of his own.

Peat must be machined, or pulped, before drying to insure its condensation. It works to best advantage at a moisture content of 66.6 per cent, or with two parts of water to one of

peat. In an undrained bog the water content is 90 per cent. The difference is best appreciated between a 90 and a 60 per cent water content in terms of tons. With 90 per cent we would have to handle 10 tons of wet peat to get one of dry, but with 66 per cent only three tons. The water in excess of 66 per cent can be removed mechanically but the great quantities makes the operation practically impossible. Below this degree of moisture, no amount of pressure will dry it further. Fortunately, it will readily drain itself to this point.

I may roughly outline some suggestions for handling peat, which may be varied and improved on to any extent.

Assuming that the bog is drainable to a depth of 10 feet, this gives us 2,000 tons to the acre. For a 100-ton plant we require in one year 36,500 tons, 18 acres. In the bog this is about 300,000 yards.

I propose to excavate this with a drag-line crane, laying out the ground in 60-ft. wide strips and piling each alternate 60 feet on the other. This will require digging 150,000 yards. The machine should be capable of handling 3,000 yards per day and the operation take 50 days. This should be done at least one season ahead of the operation of the plant.

The same drag-line machine can be used in loading the peat into standard side-dump cars. The plant requirements will be 600 tons per day. Large units are preferable, and the old style stripping car in use on the Mesabe Range, holding 10 yards, is a good type.

The peat should be stock piled from trestle at the plant and delivered to machine by mechanical loader and belt conveyor.

There are a number of clay-working machines of large capacity suitable for pulping. They are much better than anything so far specially designed for peat handling.

The first machine may have to be a grizzly for removal of roots and stumps, but these should be taken care of at the bog. The peat is passed through a standard clay disintegrating machine, delivered to a combined pug and auger machine for further pulping and molding into a continuous column through a suitable die. This part of the operation is greatly improved and condensation facilitated by enclosing this unit in a chamber from which the air can be exhausted.

The column issuing from the mill is conveyed by belt to a specially designed drying shed. Delivered by the belt to molding machines in a form to be conveniently transferred by hand to the drying racks.

The shed is calculated to hold a ten days' run and the peat dried by circulating air.

The point of dryness of the finished peat depends on the use to which it is to be put. For the Mond process no further treatment is necessary; for by-product ovens or atomised peat the product will be finished in tunnel driers of the standard clay products plant.

This operation cuts down hand labor to the lowest notch. There is only one hand operation, from the molding machine to the racks, and some one will discover the means of eliminating this.

The operating cost will not exceed $1.50 per ton and the cost of the plant will be approximately the same as a brick or tile plant intended to handle the same tonnage output.

PEAT IN THE DISMAL SWAMP, VIRGINIA AND NORTH CAROLINA.[1]*

By C. C. Osbon.

Geography.

The Dismal Swamp district is in the Coastal Plain of southeastern Virginia and northeastern North Carolina. (See Pl. IV.) It lies roughly between parallels 36° 15′ and 36° 45′ N. and meridians 76° 5′ and 76° 35′ W., and approximately includes Norfolk County and the eastern part of Nansemond County, Va., and Perquimans, Pasquotank, Camden, and Currituck Counties, N. C. As the limits of the swamp depend largely upon rainfall and vegetation, as well as topography, they are rather irregular and are not sharply defined.

The swamp is traversed from Deep Creek, Va., to South Mills, N. C., by the Dismal Swamp Canal and is cut by numerous smaller canals and ditches radiating from Lake Drummond. The Norfolk Southern Railroad skirts the eastern, southern, and western parts of the swamp, and its north end is crossed by the Virginian, Seaboard Air Line, and Norfolk & Western Railroads.

The total area of the Dismal Swamp is about 2,200 square miles, of which a little more than 700 square miles has been drained by the Dismal Swamp Canal and other ditches. A large part of the swamp is owned by the Roper Lumber Co., Norfolk, Va., and by the Richmond Cedar Works, Richmond, Virginia.

The region as a whole is but sparsely populated, and the chief industries in the reclaimed areas are lumbering and agriculture.

Geology.

The peat deposits of the Dismal Swamp lie in shallow basins that originated in an extensive depression of the Columbia group of formations. During the deposition of these formations the mouth of James River was some distance southwest of its present mouth,[2] and the sediment it laid down probably formed a bar or delta east of the swamp. When the land was subsequently uplifted the mouth of the James was diverted to its present position, and between the terrace formed by its delta and the Nansemond escarpment there remained a

[1]Some of the field work upon which this report is based was done by E. K. Soper.

[2]Darton, N. H., U. S Geol. Survey, Geol. Atlas, Norfolk folio (No. 80), pl. 1.

*Reprinted from U. S. Geol. Sur. Bul. 711-C.

large, poorly drained depression in the surface. The normal annual precipitation of the region is about 52.08 inches, and the average humidity is 73 per cent. Thus favored by topographic and climatic conditions, the surface was soon saturated or covered with water and luxuriant vegetation, and it has remained in substantially the same state since that time.

While the swamp was young most of the peat was formed below water level and the deposits were largely of the filled-basin kind. Later many basins in the region were filled to the general level of the surrounding country by vegetal accumulations, and much of the surface water was drained off through the Dismal Swamp Canal and subsidiary ditches. Thus the Green Sea, which was originally connected with the main morass, has been detached by the draining of the intervening area. Many marginal sections have also been reclaimed for agricultural use by small ditches and are no longer swampy, except in very wet weather. However, the greater part of the swamp is still so poorly drained and so choked with plant growth that it is continually saturated or covered with water. The average depth of the water is only a few inches. In the western part the water is in places 2 feet deep, and peat is still forming there under water. In the eastern part the water seldom stands above ground, although in many places it keeps the surface so highly saturated that peat is still accumulating. In the thoroughly drained sections the formation of peat has been superseded by that of leaf mold.

Flora.

The Dismal Swamp lies at the junction of the coniferous and deciduous forest regions of the eastern coast of the United States. Its flora comprises plants of a great number of species and is interesting because it shows a mingling of the northern and southern land floras. In the earlier stages of peat formation algae and mosses probably grew profusely in its shallow waters, building up deposits of fine-grained peat, which is now found in the bottoms of the basins. As the remains deposited by these plants accumulated the basins became shallower, enabling the pondweeds (Potamogeton), the water lilies (Castalia and Nymphaea), and the lake bulrush (Scirpus) to establish themselves temporarily.[1] In some of the higher parts of the morass the bog-meadow and bog-heath stages, in which the Carex and Andromeda-Ledum associations predominated, may have followed in small areas. As the surficial depressions were relatively shallow, and as logs are found in nonfibrous

[1]Davis, C. A., U. S. Geol. Survey Bull. 376, p. 13, 1909.


EXPLANATION
Area in which peat occurs
Site of test boring for peat
Site of test boring for peat
SURRY
SOUTHAMPTON
ISLE OF WIGHT
NANSEMOND
NORFOLK
PRINCESS ANNE
ELIZABETH CITY
GATES
HERTFORD
BERTIE
PERQUIMANS
CURRITUCK
CAMDEN
PASQUOTANK
CHOWAN
VIRGINIA
NORTH CAROLINA
DISMAL SWAMP
Lake Drummond
ATLANTIC OCEAN
ALBEMARLE SOUND
HAMPTON ROADS
CHESAPEAKE BAY
CAPE CHARLES
CAPE HENRY
Virginia Beach
Norfolk
Portsmouth
Suffolk
Newport News
Hampton
Deep Creek
Smithfield
Windsor
Franklin
Winton
Gatesville
Hertford
Edenton
Elizabeth City
South Mills
Moyock
Shawboro
Powells Pt
Camden Pt
Harvey Pt
Laurel Pt
Colington I
Kittyhawk
Nags Head
Roanoke I
Manteo
Woodard
Avoca
Merry Hill
Mackeys
Askewsville
Powellsville
Sunbury
Somerton
Whaleyville
Holland
Carrsville
Ft Landing
Wade Pt

peat at depths of 5 to 10 feet in many sections of the swamp, it is believed that deciduous and coniferous trees more or less fully superseded the other flora at an early date and contributed the greater part of the dead vegetation from which the peat deposits of the region were formed.

The present flora of the Dismal Swamp includes aquatic plants, the fern and peat-moss association, deciduous and coniferous trees, and associated undergrowth. Nearly the whole region is forested, and the plant associations are so intimate that it is difficult to delimit the distinct formations. However, the following ecologic classification, which follows roughly the classification used by Schenck in "Biologie der Wassergewächse," shows the most abundant plants that are now contributing to the formation of peat:

Aquatic Plants.

Submersed:
- Utricularia spp.
- Riccia fluitans.
- Philotria canadensis.
- Sphamnum kearneyi.
- Callitriche heterophylla.
- Juncus repens.
- Isnardia palustris.

Floating on the surfaces:
- Spirodela polyrhiza.
- Castalia odorata.
- Nymphaea advena.
- Nelumbo lutea.
- Potamogeton lonchites.
- Callitriche heterophylla.

Rising above the surface:
- Sparganium androcladum.
- Myriophyllum heterophyllum.
- Woodwardia virginica.
- Eriophorum virginicum.
- Decodon verticillatus.
- Limodorum tuberosum.
- Sphagnum cymbifolium.

Black Gum Association.

Water ash (Fraxinus caroliniana).
Rattan (Berchemia scandens).
Yellow jessamine (Gelsemium sempervirens).
Cross vine (Bignonia capreolata).
Water gum (Nysso biflora).
Bald cypress (Taxodim distichum).
Red maple (Acer rubrum).
Cotton gum (Nyssa aquatica).

White Cedar Association.

Loblolly pine (Pinus taeda).
Sweet bay (Magnolia virginiana).
White cedar (Chamaecyparis thyoides).
Shrubs (Ericaceae association).
Cane (Arundinaria macrosperma).

Aquatic plants are found in nearly all the wetter parts of the swamp, notably in some of the abandoned ditches, which have been completely filled with them. However, in areas of dense shade they make little headway and are of minor importance in the formation of peat.

Ferns and peat mosses are found in the open parts of the region. Sphagnum cymbifolium grows in the shallow water and among the stipes of the Woodwardia in the higher parts of the peat area. The roots are usually submerged, and the

stems, which range in length from 6 to 18 inches, rise above the surface.

The water gum, locally known as black gum, and white cedar or juniper forest associations predominate throughout the region and contribute the greater part of the dead vegetation that is now accumulating. The densely forested wetter part of the morass, especially the area surrounding Lake Drummond, is known as the black-gum swamp. (See Pl V, A.) It is characterized by the profuse growth of black gum and its associated undergrowth, although red maple is also abundant. Here immense quantities of peat are now accumulating. The bald cypress is also still found in some parts of the black-gum swamp but probably was more abundant in earlier years. In fact, the most striking feature of the region is the weird aspect presented by the cypress knees and the belt of old weathered cypress stumps standing on the margin of Lake Drummond and hung with Spanish moss. These stumps, which have survived the attacks of the elements for many years, and the numerous well-preserved cypress logs that are encountered several feet beneath the surface indicate that cypress formerly contributed much more dead vegetation to the peat deposits than now.

The open, light parts of the morass, known locally as juniper swamp, are largely occupied by the white-cedar association. In earlier years these areas were completely forested by white cedar, but now, owing in part to the work of man, many of them bear a growth of shrubs and cane. (See p. 49 B.)

Origin.

Peat is incipient coal. It is the organic residuum resulting from the arrested decomposition of leaves, twigs, roots, trunks of trees, shrubs, mosses, and other vegetation in areas continually covered or saturated with water. It may be identified as a dark colored soil found in bogs and swamps, commonly called muck, although technically the term "muck" should be restricted to soil in which the quantity of inorganic mineral nearly equals or exceeds that of the organic matter. In mild or warm climates the formation of peat is directly dependent upon abundant rainfall and luxuriant plant growth and is indirectly regulated by topographic and climatic conditions. Basins in which peat has accumulated are found in the glaciated regions of New England and of the Great Lake states and in areas like those of the Atlantic and Gulf Coastal Plain, where the seacoast has subsided and bars or deltas have formed inclosed ponds or land-locked lagoons and estuaries.

TYPES OF PEAT-FORMING PLANT ASSOCIATIONS IN DISMAL SWAMP.

A. Black-Gum and Bald-Cypress Swamp on the Eastern Shore of Lake Drummond.

B. Association of Shrubs and Small Trees Growing in Peat in the Open or Light Swamp Near Dismal Swamp Canal.

The most extensive peat deposits of the United States are in these regions. Water is next in importance to topography in the formation of peat. It performs a twofold function, enabling plants to grow profusely and protecting their remains from complete decay. In order that water may accumulate on the surface abundant rainfall and a humidity sufficiently high to prevent rapid evaporation are necessary. Where rainfall is heavy and the drainage is arrested or greatly retarded by plant growth peat sometimes forms even on level areas and gentle slopes, especially in cold or very humid climates. In these places, although the water seldom rises above the ground, it is progressively elevated as the plant remains collect, and the water table is always near the surface.

Topographic and climatic conditions that are unusually favorable for the accumulation of peat exist in the Dismal Swamp region. Many shallow basins and poorly drained level areas choked with dense vegetation are found between the Nansemond escarpment and the terrace plain to the east. Some of these depressions have already been filled with peat to the general level of the surrounding country. The climate is characterized by heavy and well-distributed rainfall, uniformly high humidity, and a temperature sufficiently low to prevent a too rapid evaporation and the complete decay of dead vegetation. The growing season is long, the winters mild, and the sunshine abundant. Thus favored by climate and moisture the plant growth in the Dismal Swamp is luxuriant, being so dense in many places that it cannot be penetrated by man without great difficulty. The central part of the swamp is so densely forested that the sun rarely shines upon the ground, and the quantity of dead vegetation that has accumulated is immense. In certain of the open parts of the swamp the canes grow very closely together, and in places the leaves, falling among them, accumulate to the thickness of one foot each year. Next to the trees and the larger shrubs the canebrakes are probably the greatest contributors to the vast quantity of organic matter which yearly accumulates upon the surface of the region.

One of the chief substances formed by plants during their growth is cellulose, which is produced from atmospheric carbon dioxide and from water supplied by the roots and which consists of carbon, hydrogen, and oxygen. If the plant debris falls upon drained soil it is immediately attacked by microorganisms and the carbon and hydrogen of the cellulose unite with atmospheric oxygen and form carbon dioxide and water. In other words, if oxidation is unhampered the organic matter will disappear in a relatively short time. If, however, the plant

matter falls into water or upon soil saturated with moisture it undergoes a change different from the decay suffered by exposed vegetation. The atmospheric oxygen is largely excluded by the moisture, and the plant substance is partly protected from the attacks of fungi and bacteria. The salient features of the evolution of peat from cellulose are the elimination of hydrogen and oxygen as water and of carbon and oxygen as carbon dioxide and the generation of methane. The evolution of water and methane exhausts the hydrogen more rapidly than the carbon. This is the process of carbonization. If surface conditions are unchanged the process of carbonization is greatly retarded upon the formation of peat, and the accumulation of organic matter may exist indefinitely as peat unless the land is drained and decomposition again begins, or unless the peat is deeply buried beneath superposed deposits, generally muds, sands, limestone, etc., and subjected to pressure, with varying degrees of heat. Lignite, bituminous coal, anthracite, and graphite are succeeding stages in the process of carbonization. It seems, therefore, that most if not all coals were once peats, that most coal fields were formerly swamps, and that the formation of peat in the Dismal Swamp is an existing example of the first stage in the process of coal formation. It has been shown that deposits essentially similar to those of the Dismal Swamp were laid down in many parts of the United States during the Carboniferous period.

DISTRIBUTION.

General Conclusions.

The Dismal Swamp covers approximately 2,200 square miles, of which a little more than 700 square miles has been permanently drained to a depth of 3 feet or more by Dismal Swamp Canal and smaller ditches. (See map.) Much of the drained land is farmed. In the remaining 1,500 square miles peat deposits ranging in depth from 1 foot to 20 feet are found. The thickest beds lie in the region east and northeast of Lake Drummond, where peat 18 feet deep was exposed by comparatively recent excavations. The peat in this area is black and low in inorganic impurities and is probably the best in the swamp. In general, the depth of the peat gradually decreases toward the edge of the swamp, where the peat finally merges into the sands of the adjoining areas. The eastern border is deeply indented by large tracts that have been drained, cleared, and cultivated. Some peat of value is found in the southern and southeastern parts of the morass, but the northern and western parts contain few deposits large enough to be of commercial importance.

The Dismal Swamp is not entirely covered with peat—in fact, not more than half of it contains peat of commercial value. In some parts of the swamp the peat is too shallow to be worked profitably, and in others it contains so many roots, stumps, and logs that excavation by present methods would be impracticable. In many areas the peat has been destroyed by forest fires. In some of the heavily forested areas peat has never formed to great depths, perhaps because of the presence of excessive surface water and dense shade, which prevented the growth of shrubs, mosses, grasses, reeds, ferns, and other prolific peat-forming plant. From numerous test borings, observations made along the banks of drainage canals, and information furnished by drainage engineers who are familiar with the swamps, it is estimated that the average thickness of the peat is 7 feet. On the assumption that the uncultivated area of the Dismal Swamp is 1,500 square miles, that about one-half of this area is covered with peat averaging 7 feet in depth, and that, according to the usual practice in estimating the tonnage a bog will yield, 200 tons of dry peat per acre-foot may be obtained, then the total available peat in the Dismal Swamp is 672,000,000 tons.

AREAS TESTED.

Virginia.

NORFOLK COUNTY.

The best peat in the Dismal Swamp is found in Norfolk County, Va., in the territory northeast of Lake Drummond. This area is close to the truck-farming section of Virginia, to which the peat could be cheaply transported by means of the Dismal Swamp Canal. As shown by the table of analyses on page 55, much of this peat is high in thermal value and contains relatively little ash and a fair percentage of nitrogen. It could therefore be used as fuel as a nitrogenous ingredient of commercial fertilizer.

It is reported that in 1860 a peat-fuel plant was erected near the site of hole A, described below, but that on account of economic conditions which arose with the outbreak of the Civil War it was unsuccessful and the machinery was dismantled. So far as known, this is the only attempt that has ever been made to market peat from the Dismal Swamp.

As shown on map, test borings for peat were made along the Norfolk & Western Railway, the Dismal Swamp Canal, the canal feeder, and the eastern shore of Lake Drummond. No peat of consequence was found in the region trav-

ersed by the railway, but in the other areas the test borings gave the following results:

Hole A was drilled at a point one mile north of Wallaceton and 300 feet east of Dismal Swamp Canal. Nonfibrous peat, ranging in color from dark brown to black, was found to a depth of 10 feet. Sample 1 was taken at a point four feet from the surface, and sample 2 at six feet. (See table of analyses on p. 55.)

Hole B was made on the north bank of Northwest River, 300 feet east of Dismal Swamp Canal. Here nine feet of peat similar in physical characteristics to the specimens taken from hole 9 was found. Samples 3 and 4 were taken at depths of four and six feet, respectively.

Hole C was sunk to a depth of nine feet at a point midway between the sources of Jericho Canal and of the feeder ditch by which water is supplied to Dismal Swamp Canal. About eight feet of peat, underlain by white sand, was found here, but as it seemed to be similar to the material from holes A and B no sample was taken for analysis.

Hole D, in which 10 feet of peat underlain by alternate layers of white sand and blue clay was found, was made 200 feet north of the water gate in the Dismal Swamp Canal feeder. The surface layer of this peat is black and well decomposed, but the subsurface layers range in color from dark to light brown. Sample 5 was taken four feet below the surface.

Hole E was drilled on the bank of Dismal Swamp Canal opposite the mouth of the feeder. As the peat was rather fibrous and only three feet deep at this point it was not sampled for analysis.

NANSEMOND COUNTY.

Hole F was sunk on the south side of Washington Ditch about a mile northwest of Lake Drummond, in Nansemond County. This boring, as well as four others at intervals of three-quarters of a mile northwestward along this ditch, failed to show peat in commercial quantities. From one to three feet of muck was found, and sample 6, consisting of a composite mixture of material from the surface to a depth of three feet, was taken in order to show its character. The absence of peat in this area may be due to the dense stand of mature timber and the excessive quantity of water that cover it, preventing the growth of shrubs, mosses, and other prolific peat-forming plants.

North Carolina.

CURRITUCK COUNTY.

Hole J, in Currituck County, N. C., was put down on the

north side of Old Swamp Road about 800 yards northeast of the line between Currituck and Camden Counties. It penetrated seven feet of black, thoroughly decomposed peat. The area of this deposit is approximately 100 square miles, and for the most part the material is of the built-up type, though the deposit contains some filled-basin peat. As shown in the table of analyses on page 55, the peat is unusually high in thermal value, contains little ash and a relatively high percentage of nitrogen, and seems to possess much value as a source of fuel and fertilizer.

CAMDEN COUNTY.

Holes G, H, and I, which were sunk half a mile apart along Dismal Swamp Canal, from half a mile to one and a half miles northwest of Lilly, Camden County, N. C., failed to show peat of commercial value. Muck averaging three feet in depth was found, but it was not sampled. These tests, however, do not prove that there is no peat in workable quantities in the county. The vegetation in the region consists chiefly of maples, sedges, grasses, canes, ferns, and mosses. Sphagnum moss suitable for surgical dressings is abundant, and it is reported that pure sphagnum covers many square miles in the territory west of Dismal Swamp Canal.

CLASSIFICATION AND PROPERTIES.

Physical Character.

The two leading kinds of peat in the Dismal Swamp are known locally as "black-gum peat" and "juniper peat." The former, which is dark brown or black, thoroughly decomposed, and relatively homogeneous in structure, is found in what were formerly the wetter parts of the region, especially near Lake Drummond, and bears a growth of black gum, red maple, and bald cypress. It is well humified and almost destitute of fibrous structure. When dry it breaks easily, leaving lusterless fracture surfaces. "Juniper peat," which ranges from dark to light brown in color and is rather fibrous, is found in the light or open swamp and bears a growth of white cedar, pine, sweet bay, shrubs, and cane. Decomposition is not far advanced and the peat contains many stems, roots, and logs. On the eastern margin of the swamp near the source of Northwest River there is a typical area of this material. When dry it hardens in lump form and breaks with difficulty.

Chemical Character.

Analyses.

The following table shows the results of analyses of Dis-

mal Swamp peats both as received in the laboratory and after the moisture had been eliminated. These samples were dried to about 50 per cent moisture in the field and shipped to the laboratory in canvas bags.

Analyses of Specimens of Peat and Muck from Dismal Swamp, Virginia and North Carolina.

(H. M. Cooper, assistant chemist, Bureau of Mines, analyst).

				Proximate.				Ultimate		Calorific value.	
Locality.	Sample No.	Hole.	Condition of sample. a	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calories.	British thermal units.
Virginia.											
Norfolk Co....	1	A	1	14.01	45.42	33.92	6.64	0.31	1.73	4,690	8,442
			2	.....	52.82	39.46	7.72	.36	2.01	5,454	9,818
Do	2	A	1	32.93	42.42	19.62	5.03	.23	1.38	3,655	6,578
			2	.....	63.25	29.25	7.50	.34	2.06	5,449	9,808
Do	3	B	1	17.93	46.57	20.15	15.35	.19	1.31	4,052	7,293
			2	.....	56.74	24.56	18.70	.23	1.60	4,937	8,886
Do	4	B	1	18.88	47.55	18.49	15.08	.19	1.27	4,021	7,238
			2	.....	58.62	22.79	18.59	.23	1.57	4,957	8,923
Do	5	D	1	9.38	48.05	18.72	23.85	.28	1.67	3,881	6,985
			2	.....	53.02	20.66	26.32	.31	1.84	4,282	7,708
Nansemond Co.	6	F	1	6.43	30.32	10.92	52.33	.25	1.07	.....	.....
			2	.....	32.40	11.67	55.93	.27	1.14	.....	.....
North Carolina.											
Currituck Co..	7	J	1	8.23	52.05	33.54	6.18	.26	1.60	5,163	9,294
			2	.....	56.72	36.55	6.73	.28	1.74	5,626	10,127

a 1, As received in the laboratory; 2, moisture free.

Conclusions.

"Black-gum peat" (samples 1, 2, and 5), because of its thorough decomposition, contains more nitrogen and fixed carbon than "juniper peat" (sample 4), and therefore is less acidic. It also contains less ash and is of greater commercial value. Where the ash content exceeds 8 per cent it consists chiefly of alumina and silica in the form of clay and sand.

ASSOCIATED MARL.

Shell beds or so-called marls underlie the peat deposits at many places in nearly all the counties of the Dismal Swamp region. Although no outcropping beds were observed in the areas tested for peat, it is said that many of these strata have been penetrated by wells and extensively exposed by drainage excavations. Shells thrown upon the bank of Dismal Swamp Canal by dredges were seen near Deep Creek and Wallaceton, Va., and Lilly and Moyock, N. C. Several years ago a dredge

of the Lake Drummond Canal & Water Co., in deepening the canal feeder penetrated a shell bed about midway between the source and mouth of the feeder. A large quantity of shell "marl" was thrown upon the bank at this point, but on account of the action of the dredge and of the weather since that time it is now disintegrated and mixed with sand and clay. W. C. Mansfield, who identified the following fossils collected at this locality, believes that they are of Pleistocene origin:

Venus mercenaria Linné.
Ostrea virginica Gmelin.
Arca transversa Say.

It has been said[1] that the age represented by these fossils is Pliocene, but as they are also found in the Pleistocene and underlie peat of late Pleistocene origin, it is probable that they belong to the Pleistocene series.

An estimate of the quantity of shell "marl" in the Dismal Swamp region is not available, but if the material occurs in workable quantities and can be cheaply excavated, many peat areas in this region that on account of the acidity of the soil are now valueless for general farming could perhaps be economically treated with lime from these shell beds and made to yield large alkalin-soil crops.

USES.

General Uses.

The products that may be made from peat are numerous and varied. In Europe it is shaped into blocks and used for fuel. Gas, charcoal, and coke are produced from it, as well as ammonium sulphate and a number of other valuable by-products. Owing to the scarcity of raw material in the countries of northern Europe peat moss is employed as packing material, as a substitute for absorbent cotton in the preparation of surgical dressings, and in a small degree for wood and for cotton and woolen cloth. In the United States peat is used as a soil for the cultivation of certain crops and to some extent for fertilizer, stable litter, and fuel, and for compounding stock feed. It is believed, however, that the greatest possibilities presented by peat in this country are in agriculture and as a source of fuel.

Peat Soils.

Peat, when properly treated, is one of the most fertile soil types in this country. In previous years, owing to the

[1] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Norfolk folio (No. 80), p. 3, 1902.

COMMERCIAL PRODUCTS OF PEAT.

A. Wheat Grown by the Wallace Brothers Near Wallaceton, Va., on Reclaimed Peat Land.
Photograph by John G. Wallace.

B. Machine Peat Fuel Prepared at the Experimental Peat-Fuel Plant of the Canadian Department of Mines, Mines Branch, Alfred, Ontario, and Spread for Air Drying on the Surface of the Bog.
Photograph by E. V. Moore.

abundance of well-drained land that could be more readily tilled, the peat and muck areas have been passed by, but with the rapid increase of our population and the advent of intensive soil cultivation the attention of agriculturalists is now being directed to these neglected lands. Raw peat soils, though too acidic for ordinary farming, are, after they have been drained, cleared, and freely aerated, especially well adapted to the production of vetch, buckwheat, oats, rye, some varieties of corn, the cranberry, the strawberry, the blueberry, potatoes, and other acid-soil crops.[1] If properly treated with potash salts and with lime they are neutralized or made slightly alkaline, and should then yield large quantities of red clover, wheat, timothy, alfalfa, sugar beets, rutabagas, and other alkaline-soil crops. (See page 57). The greatest values derived from the cultivation of peat and muck, however, have arisen from their use as special crop soils. According to the Bureau of Soils,[2] cabbage, onions, celery, lettuce, spinach, carrots, beets, turnips, and peppermint are the most valuable crops that are grown on treated areas of peat and muck. The values of these crops per acre so far surpass those of the general farm crops that the reclamation of any large areas of peat or muck should be undertaken with the special object of their production. For the profitable sale of these special crops it is desirable that such areas of peat and muck as are easily accessible to large city markets or to rapid transportation should be reclaimed first.

The fertility of peat and muck soil is due chiefly to its nitrogen content, to its affinity for moisture, and to its black color, which enables it to absorb heat.

In the Dismal Swamp the areas of black peat land seem to be the most valuable for agriculture. As decomposition is well advanced in these areas the soils contain much nitrogen, are easily worked, and afford a mellow top soil radically different from that of the juniper lands, which cakes and hardens when exposed to the rays of the sun. Because of its pronounced acidity and of its unfavorable physical condition the juniper peat is of little value for general farming unless subjected to intensive treatment. However, frequent plowing, which stimulates the growth of aerobic bacteria, and the application of lime will usually correct these conditions.

On page 56 is mentioned a source from which lime might be economically obtained and applied to this land. Although shell "marl" possesses less value as a fertilizer than commercial lime, it is beneficial to peat soils. Where it has been prop-

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[1]Coville, F. V., The agricultural utilization of acid lands by means of acid-tolerant crops: U. S. Dept. Agr. Bull. 6. 1913.

[2]U. S. Dept. Agr. Bur. Soils Circ. 65. pp. 13, 14, 1912.

erly used in Virginia, its application has resulted in increased soil fertility. The shells should be burned or ground before the material is used as fertilizer, because the lime is then available immediately, whereas if the material is applied in an untreated condition the lime is relatively inactive the first year. The chemical and physical effects of liming are manifold: it releases potash from certain silicates; it promotes the decomposition of the peat, freeing soluble nitrogen; it corrects the acidity of sour soils; and peat soils that harden in lumps on drying are made friable by treatment with lime.

Peat Fertilizer.

The value of peat as a source of nitrogen for use in the growth of crops seems to have been overlooked by many persons who are interested in the development of a domestic peat industry. Analyses of the peats of the United States show a nitrogen content ranging from 1 to 4 per cent, and averaging about 2 per cent. This nitrogen can be extracted from the peat as a by-product in producer-gas plants or can be made available for plant food without segregating it from the peat. A discussion of the recovery of nitrogen from peat as a by-product in the manufacture of gas is given on pages 65-66.

The use of peat as a culture medium for nitrifying bacteria is now attracting wide attention, and it is believed that this feature of the peat industry offers attractive possibilities. A chemical analysis of raw peat is not a true test of its value as a source of nitrogen for agricultural use, because if the peat is limed and properly inoculated with nitrifying organisms a substantial quantity of soluble nitrogen is gradually formed and released after the peat has been placed on the soil. Arguments are often advanced against the use of peat as a source of nitrogen in soil fertilization because all the nitrogen shown by chemical analysis is not readily available for plant food, but these arguments seem to be based on a misconception of the nature of peat. It is true that only a part of the actual nitrogen content of peat shown by a chemical analysis can be immediately used for food by plants, but it is equally true that the total quantity of potential soluble nitrogen formed and released by bacterial action from time to time after the peat has been applied to the soil is much greater than the percentage found in some commercial fertilizers. Fortunately not all the nitrogen in peat is soluble, or it would leach out and the black peat soils of this country would be barren.

Peat has been used commercially in the United States in soil fertilization since 1908, having been mixed with potash or phosphate, limed, treated with nitrifying organisms, and ap-

plied as a direct fertilizer, or used as a nitrogenous ingredient of commercial fertilizers. For these purposes properly treated peat is valuable both chemically and physically. Its content of soluble nitrogen is immediately available for plant food, and it is potentially rich in nitrogen that is gradually released as needed for plant growth; it contains small quantities of potash and phosphorus; it supplies humus, a vital requirement for plant life under natural conditions of growth; on account of its black color it absorbs heat; soils to which it is applied are made friable and can be readily worked; and its water-holding properties are proverbial. Because of these characteristics peat is being used more and more in the manufacture of commercial fertilizer.

To those who propose to enter this branch of the peat industry it is suggested that caution be observed in selecting a suitable deposit. Before any money is invested a careful survey should be made of the prospective bog to determine whether there is a sufficient quantity of peat to justify the erection of a plant. Typical samples should be taken from different parts of the deposit and examined to determine whether the material is chemically adapted for fertilizer. Black, well-humified peat is most satisfactory for soil fertilization, as such material is generally more compact and contains more nitrogen and less fibrous material than the brown peat. Only bogs containing peat that is rich in nitrogen should be selected. The acidity of the raw peat must be corrected by thorough aeration and liming before any attempt is made to market it. One of the greatest handicaps suffered by the peat fertilizer industry in this country has been the lack of uniformity in its product, and as the success of a plant depends upon the character of the material used, too much caution cannot be observed in selecting it.

Of equal importance to the kind of peat used are the process and machinery employed in refining it. The deposit must first be drained and cleared of trees, brush, and turf. Cultivation of the peat for several seasons will correct the acidity and afford means for determining its general agricultural value. After the upper layer has been plowed, disked, and harrowed, the peat is excavated to a depth of about three feet and left in windrows on the surface of the bog. When the moisture has been reduced to about 50 per cent by air drying the material is scraped in piles, loaded in cars, and hauled to the stock pile. After aerobic fermentation is well advanced the material is run through heated rotary dryers until the moisture is lowered to 10 per cent, screened, and cooled. The resulting product contains humus. This material may be further enriched with

nitrogen by liming and appropriate inoculation, and if a complete fertilizer is desired, potash, phosphorus, and other minerals are intermixed with it.

The outdoor equipment consists essentially of agricultural implements, excavators, scrapers, loaders, some light rails, a few cars and small locomotives, an elevator to raise the peat to the top of the stock pile, and a conveyor for transporting it to the dryers. If possible the excavators, scrapers, and loaders should be electrically propelled and operated with caterpillar drives, as machinery so equipped gives little trouble on boggy surfaces. The indoor equipment consists of engines, boilers, dynamos, rotary dryers, and sifters. The building containing the drying plant should be fireproof and should be located as near the deposit as possible.

In order that the plant may run throughout the entire year, it is the best practice to excavate and pile up as much peat as possible during the air-drying season and to complete the drying artificially as the material is needed. By adopting the process and equipment described lost motion is minimized and a large proportion of the water in the peat is eliminated in the field.

Farmers who own small bogs can prepare peat fertilizer by composting the raw peat with manure, and after the bacteria have saturated the mixture it may be applied to the soil in the same way as manure. Land that is deficient in humus and nitrogen will thus be materially benefited.

The peat deposits of the Dismal Swamp are within a short distance of many sandy truck farms, to which the peat could be cheaply transported by water, and it seems that peat fertilizer plants in this region should be successful.

Peat Fuel.

Peat, because its carbon content is higher than that of wood and because it will ignite and burn freely when dry, yielding an intense heat, is used for fuel in countries where the coal supply is below normal requirements. In Ireland peat has been the only domestic fuel of the common people from the traditional time when that country was deforested. It is one of the essential elements of Irish national life, and in many villages remote from modern routes of transportation hand-cut peat is the only fuel available. The peat fire on the hearth, like the jaunting car, typifies Irish environment, and when the tourist seeks a memento of his visit to that country he usually selects some souvenir carved from the black oak that has lain for centuries protected from the attacks of fungi and bacteria by peat.

Although between 15,000,000 and 20,000,000 tons of peat fuel is annally produced in Europe and consumed in generating heat and power, only small quantities of peat fuel have been produced in the United States, because of the abundance in normal times of coal, which is more efficient and could heretofore be more cheaply prepared and more readily transported to the consumer, so that the interest shown in the peat in this country has been largely scientific and experimental. In recent years, however, the increasing cost of producing coal and the temporary failure of the operators to keep pace with the ever-expanding demand have led to a general advance in price. This condition, aggravated by an appreciable reduction in the visible coal supply and the rapid exhaustion of our forests, has made a marked impression upon economists and others and has created a desire to conserve these materials by investigating and substituting other fuels and sources of power wherever they can be more economically used. The late Prof. Van Hise,[1] in urging the conservation of our wood and coal reserves, said:

"So far as practicable other products should be substituted for wood. The original forests of the United States contained not less than 850,000,000 acres, having not less than 4,800,000,000,000 feet of merchantable saw timber. This was our magnificent original heritage. The United States as a nation has existed a century and a quarter, and what have we now? In that brief time approximately one-half of the value of our forests has gone.

"So far as practicable substitutes should be used for coal. Even if all possible economies and substitutes are introduced, the most sanguine can not hope that the supply of fuels will be sufficient to meet the needs of the people for more than a small fraction of the time we look forward to as the life of this nation."

In the northern peat region there are no known coal fields, except in small sections—notably in Michigan—and the peat deposits are confined largely to States which, because of their cold climate and extensive manufacturing industries, consume large quantities of fuel. In the southern part of the coastal region, although the climate is mild and the demand for fuel relatively light compared with that in the Northern States, there are no local sources of high-grade mineral fuels. The preparation of peat fuel from the deposits in these regions would not only increase the local fuel supply, but would release railroad cars that are needed for other purposes. Peat there-

[1]Van Hise, C. R., The conservation of natural resources in the United States, pp. 210, 256, 359, 1910.

fore has great potential value as a source of heat and power; it may be used locally in some States during economic and industrial crises to prevent a fuel shortage; it may be utilized to conserve our resources of coal and wood; and it is thought by many that in some sections remote from the coal fields, notably in New England, peat could successfully compete with other fuels for both domestic and industrial use.

The attempts made in past years in this country to produce peat fuel on a commercial scale have not been successful, but the failure appears to have been due not to a lack of market for the product nor to the lack of merit in peat. In practically every instance it may be accounted for by the lack of sufficient capital, the inexperience of operators, the failure to recognize that peat is inferior to coal, or preventable engineering errors. Many extravagant claims concerning the fuel value of peat have been made, but the sooner its inferiority to coal is recognized the better for the peat industry. Over $1,000,000 has been spent in this country in the attempt to produce some form of peat fuel equal to coal in heating value, and yet we have no large peat-fuel industry.

Careful consideration of all the factors involved leads to the conclusion that peat fuel can now be marketed commercially in the United States only in two forms—air-dried machine blocks and powder. (See p. 49.) Many attempts have been made both in Europe and in the United States to manufacture peat briquets for commercial use, but, although these briquets are more efficient than machine or powdered peat, the process, on account of the high cost of production, has never advanced beyond the experimental stage. Peat in an undrained bog contains about 90 per cent of water, which must be reduced below 30 per cent before the peat can be used for fuel. By thoroughly draining the deposit approximately 10 per cent of the water contained in the peat may be eliminated, but the remainder, which is held in the microscopic plant cells and minute intercellular spaces, resists the greatest obtainable hydraulic force, and can not be reduced far below 70 per cent without drying in the open air or in a heated chamber. However, artificial drying as a process requires the expenditure of so much heat in comparison with the heat obtainable from the fuel prepared by this method that it has not proved commercially feasible. Peat fuel should therefore be excavated, macerated, and shaped into blocks during the air-drying season, which in the United States begins in April and ends in October, except in the southern peat region, where it is a little

longer. As Director Haanel,[1] of the Canadian Commission of Conservation, Mines Branch, has so well put it:

"The forces of nature, the sun and the wind, which cost nothing, should be used, and any improvement in this process will lie in the direction of labor-saving devices."

Air-dried machine peat is suitable for both domestic and industrial purposes. In calorific value a ton of machine peat is equal to about 1.3 tons of wood, 0.5 ton of good bituminous coal, and 0.6 ton of anthracite. It is clean to handle and burns freely, yielding an intense heat and producing no soot or other objectionable deposit. For open grates this fuel is nearly ideal, and it is said that peat may be burned in the same stoves as coal and wood. However, the best results in household use could probably be obtained by burning it in a stove with relatively small grate openings and a restricted draft.

The machinery for the manufacture of peat blocks consists essentially of an excavator, macerator, and spreader, which may be separate machines or combined in one. After the peat has been dug it is thoroughly ground into a homogeneous pasty mass and spread from 8 to 12 inches thick on the surface of the bog, and the blocks are marked off by hand as the spreading proceeds. (See page 57.) When partly dry the bricks are loosely stacked in piles. Machine peat that is allowed to dry slowly in this way contracts into a dense mass, covered by a gelatinous skinlike substance called hydrocellulose. After the moisture has been reduced to about 25 per cent this coating renders the peat impervious to water, even when immersed.

Owners of small bogs who desire to prepare peat fuel for home use should adopt the hand-cut process, which is widely used in Ireland. Before this method can be employed the deposit must be thoroughly drained and cleared, and the turf removed from its surface. Most bogs of the built-up type—that is, those which were formed by the deposition of the remains of plants that grow near the ground-water level—can be drained to the bottom by a simple system of surface ditches. Filled basins, in which the deposit has accumulated below a permanent water level, can not generally be drained far below the surface of the peat without incurring great expense and are therefore not so well adapted to hand digging as built-up beds. However, many a filled-basin deposit in the northern peat region, where most of the depressions in which peat has accumulated were formed during the Wisconsin or last glacial stage, may be sufficiently drained for peat recovery by means

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[1] Haanel, E., Peat as a source of fuel: Canadian Comm. Conservation Ninth Ann. Rept., reprint, p. 16, 1918.

of a short canal connecting the edge of the basin at the lowest level with an adjacent stream.

After the surface of the bog has been cleared, the peat is dug in brick form, with a special tool, called a "slane." This instrument, which can be made by any blacksmith, is a narrow spade, with a sharp steel lug welded on one side at right angles to the edge of the blade. The blocks of peat range from 8 to 10 inches in length, from 4 to 7 inches in width, and from 3 to 6 inches in thickness, their dimensions depending on the size of the slane. As they are dug they should be removed to the drying grounds and stood on end or placed on covered racks. At the end of about four weeks, during which they should be frequently turned until their moisture content is reduced to about 30 per cent, the blocks are usually ready for storage. As cut peat absorbs water rapidly, great care should always be taken to protect the dry blocks from rain. Peat fuel, prepared in this way, is bulky, is easily crushed, and burns rapidly, with considerable waste. In heating value it is superior to wood, but it is unfitted for commercial use.

For certain commercial uses powdered peat has many advantages over machine peat, as it can be more cheaply prepared and more readily handled. The cheapest way to prepare this product is by the air-drying process, by which the moisture may be reduced to 50 per cent in the field and to about 25 per cent under cover. However, if raw peat is allowed to lie in heaps until natural drainage and evaporation have reduced the moisture content to about 50 per cent, it may be prepared for use under steam boilers by driving off about half of the remaining moisture with waste heat from flues or other sources and pulverizing the resulting material. The powdered peat may then be blown with compressed air into the furnace, where by means of forced draft, ignition is almost instantaneous, and instead of burning on the grate, the peat forms a gas which gives a uniform fire throughout the combustion chamber. Good peat thus treated, when burned in furnaces designed to give the most complete and efficient combustion, will generate nearly as much energy in the form of live steam as the same weight of powdered coal. According to reports in this country, powdered peat has great possibilities, not only for boiler firing, but for metallurgic work and for use in cement and other kinds of kilns in which powdered coal has been successfully burned.

Peat consumed in a properly designed gas producer yields gas of good quality and in abundant quantity in comparison with the yield from coal, and also many valuable by-products. This is, perhaps, the most effective utilization of peat fuel for

generating heat and power, because peat that is to be used in this way does not need to be so carefully prepared nor so thoroughly dried as peat that is to be consumed for domestic purposes or under steam boilers.

Analyses of the peats of the United States show that they are rich in combined nitrogen, from 70 to 85 per cent of which —a proportion that in some peats amounts to more than 2 per cent of their dry weight—can be recovered in the form of ammonium sulphate in by-product gas-producing plants. According to the Mond process, which has proved successful abroad, the crushed peat is fed into the furnace of a gas producer, in which combustion is regulated by steam and hot air. The peat burns at the bottom of the feed shaft and, reacting upon the steam, forms water gas and ammonia. These gases are next cleansed of tar by means of a scrubber and are subjected to a fine shower of sulphuric acid, which converts the ammonia into ammonium sulphate and purifies the water gas. After being cooled the water gas may be used under steam boilers, in internal-combustion engines, and for other purposes. It is said that at Cordigoro, Italy, peat containing 2.5 per cent of combined nitrogen, when treated in this way, yielded 170 pounds of ammonium sulphate to the ton. Gas-producing plants using peat fuel have been operated in England, Ireland, Germany, Sweden, Italy, and Russia, but in the United States, although experiments have been made, no such plants are operated with peat.

PEAT LAND RECLAMATION IN GERMANY*

The following is an account of the present-day methods of peat land reclamation in Germany, written by Mr. G. B. Farlam, who was taken prisoner of war in May, 1915, and who, after spending a few months in a German hospital recovering from wounds, was drafted to the Royal Prussian Lands of Ostenholzer Moor, Hanover, where he was put to work as a laborer on the extensive reclamation scheme then in operation under the direction of the Prussian Ministry of Agriculture.

During the three years Mr. Farlam was kept at this work he made notes of the results of his observations, and he is to be congratulated on his endeavor to extract, in spite of the difficulties and hardships of his position, such information as he thought might be of use or interest to his own country.

Reclamation and Cultivation of "Deep" Peat Lands.

Preliminary.—The writer's experience was obtained on the Royal Prussian Lands of Ostenholzer Moor, Hanover, about the latitude of the Central Midlands of England. The work was directed by officials of the Prussian Ministry of Agriculture.

Ostenholzer Moor is a low-lying moor of approximately 18,000 acres. Of this approximately 11,000 acres was under government control, the remainder being under control of a local authority corresponding to an English County Council. Plans had been made for drainage, cultivation, and division into small holdings, of the whole moor. The work in the portion under the "County Council" was much further advanced, several small holdings having been under occupation by peasants for several years.

The central portion of the moor was peat land with peat to a maximum depth of 12 yd. The stratum below the peat consisted of sand and gravel. Large tracts on the edge of the peat were sand, and these had mostly been afforested about 1885-7. Certain portions of the peat land had also been afforested at the same time. On the peat lands the natural growth was heather, a little grass of very coarse nature also growing in certain places. The peat was of a very fibrous nature, and of a light brown color when dry. It was of little value as fuel, not being solid enough, but had been used for manufacturing peat moss litter. At the end of 1918 several thousand acres of this land had been fully drained, but owing to scarcity of labor, materials, and especially of artificial manure, only about 450 acres of peat land were actually under cultivation in the portion

*Reprint—Journal of the Board of Agriculture, 1919, Vol. 26, p. 691.

under Government control. About 2,000 acres were under cultivation in the portion controlled by the "County Council." The methods adopted by the two authorities were similar in every respect.

Previous Cultivation.—The whole moor had been roughly drained by surface ditches of about a yard deep about 1880, for the purposes of buckwheat cultivation. This came to an end about 1895, and nothing further having been done these ditches were of little value as a means of drainage.

Methods of Drainage.—In the first place a system of main drainage canals had been dug over the whole length of the moor (see Fig. 1). These canals were placed at a regular distance of 530 yd. apart, dividing the whole moor into parallelograms. These drainage canals were 7 ft. wide at the surface, sloping down to 3 ft. wide at the water level, and averaged about 7 ft. in depth (see Fig. 4). They had 0.2 per cent fall, i. e., about 7 in. per 100 yd., and discharged into a larger canal, which discharged into the River Aller. For drainage purposes, the land was then surveyed out into smaller rectangles, so arranged that the length of the primary lines of drainage pipes ("farm tiles") should never exceed 150 yd. (see Fig. 2). These were laid out by a surveyor, and a complete system of trenches 1 yd. wide and 1 yd. deep was dug, and allowed to remain open for a year, during which time the land dried up sufficiently for further working. Trenches could not be dug to full depth right away as the land was so wet that the sides collapsed.

Immediately previous to pipe-laying the trenches were deepened to the necessary extent, the floor of the trench being made as flat as possible. Guide wires were fixed along the side of the trench under the direction of the surveyor, to show the correct depth. The pipes were laid on beds of heather cut in the immediate neighborhood of the work, and a further covering of heather was placed on top. The trenches were then immediately filled in. Pipes should not be laid less than 5 ft. deep, and as great a fall as possible should be given, not less than 0.5 per cent.—half-a-yard per hundred. Pipes should be laid not more than 21 yd. apart, and in very marshy places 15 yd. Boards may be used in very marshy places to support the drain pipes. The writer saw drains laid by this method working well 10 years after being laid; pipes with 2 in. internal diameter were chiefly used, the collecting drains being laid with suitably larger pipes. It is important to note that drains must be laid as soon as possible after the trenches are deepened, on account of the danger of collapsing.

FIG. 1.—Sketch Map of Ostenholzer Moor, showing Drainage System. A, B, C, E, F, G, H, I, Canal with occupation road, D, Canal with light railway. Boundary of Government property. J, K, L, Traverse roadways.

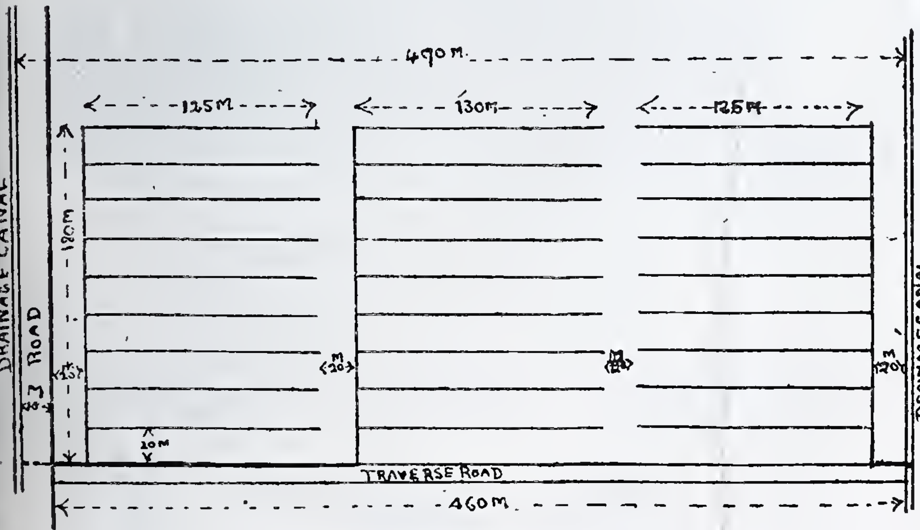


FIG. 2.—Drainage Systems.

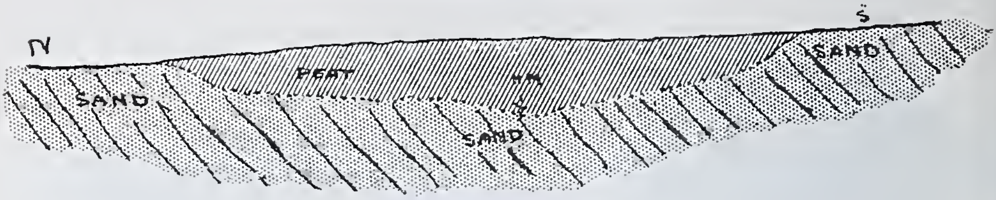


FIG. 3.—Cross Section of Moor, from North to South (Not to Scale).

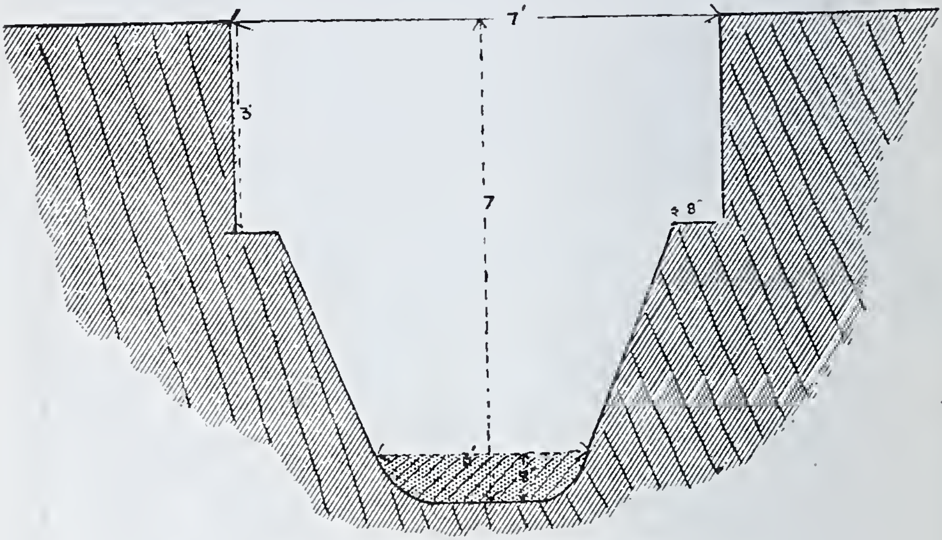


FIG. 4.—Section of Drainage Canal.

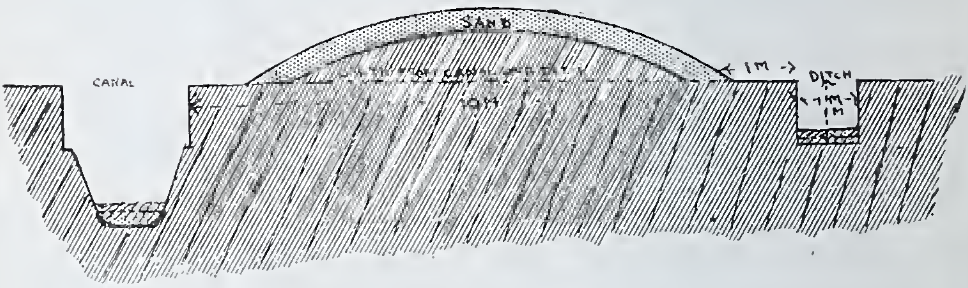


FIG. 5.—Cross Section of Roadway and Canal.

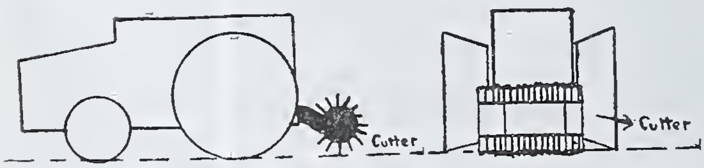
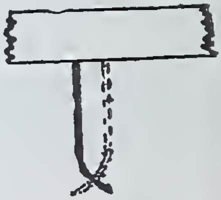


FIG. 6.—Sketch of Cultivation Motor.



Detail of Knives.

One man accustomed to the work can dig an average of about 20 cub. yd. of peat per diem. Therefore, for 1 acre of ground the labor required would be:—

Preliminary drainage	about 10	working days.*
Deepening trenches	" 5	" "
Pipe laying	" 3.5	" "
Filling in	" 5	" "

This gives a total per acre of 23.5 working days, or an actual labor cost alone of £9 8s. per acre, assuming the present standard rate of wages of 8s. per day be paid.

It is also to be noted that the work is not of a pleasant nature. The laborer is working in water practically all the time, and water-tight knee boots are essential. The fibrous peat is difficult to cut and has a tendency to stick to the shovel, and as the wet peat is heavy, and every shovelful must be thrown well clear of the trench, the work becomes very hard.

Roadways — "Occupation" roadways were made along every canal, and cross roadways as shown in Fig. 1. These were made as follows: The earth from the canal, and from a ditch a yard wide and a yard deep dug 11 yd. away, was piled in the future roadway, leaving 3 ft. clear on each side (see Fig. 5). This earth was banked and leveled as neatly as possible, and was then covered to a depth of 8 in. with sand. This made roads that would stand the necessary traffic. The sand was dug in the neighborhood, and was transported by means of a narrow-gauge temporary railroad. It is calculated that each yard of road prepared like this means one working day, and each yard of canal and roadway two working days. In the case of this moor there were approximately 10 yd. of canal and 12 yd. of road per acre, i. e., 22 working days. Thus, before cultivation commences, and without allowing for overhead expenses, expenses of management, cost of materials, cost of light railway, etc., there are to be reckoned 45.5 working days per acre, which at 8s. per day gives a labor cost of £18 4s. per acre.

These figures may be regarded as a minimum, as they assume that every man is an experienced and willing worker.

Cultivation.—The land was left for at least one summer after drainage, if at all wet. The surface was then cut into small pieces by means of a motor-driven machine of special design (see Fig. 6) called a cultivation motor (Landbau motor). This machine was of 60 nominal horse-power, and was manufactured by the firm of Henrich Lanz of Mannheim, and cost

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*A "day's work" means the amount of work which could be done by an efficient workman during a day of 9½ hours.

33,600 marks, say, £1,680, in 1916. It was supported on large wheels with a very broad rim, in order not to sink, and could cut the surface ground up very finely at the rate of 10 acres per day. It was also used without the cutter for drawing seeding macninery and rollers.

Before "ploughing" the land was treated with a dressing of a preparation of lime consisting of lime burned with about 10 per cent of clay ("Kalkmergel"). The advantage of this over quicklime is that unless actually exposed to the rain it remains dry and pulverized. This compound is advised to be used up to 4 to 5 tons per acre, but the average application here was only 35 cwt. per acre, as larger supplies were unobtainable. This compound should also be used at the rate of 5 cwt. per acre every succeding year, for the first few years, and it may be said, in general, that the more lime that is applied the better the crops. It was taken on the land by a narrow-gauge railway, and then spread by machinery of the usual type drawn by horses. The acidity of the ground, unless counteracted by lime, was shown by a thick growth of sorrel, a sure indication of acid soil, and any portions of the land which by chance had not received a fair application could be noted, owing to the poor crops and a plentiful growth of this weed.

After ploughing, the land was also dressed with applications of basic slag, crude potash salts, and calcium cyanamide. These applications varied in quantity, not only for various crops but also because under war conditions supplies were scarce and irregular.

For leguminous crops cultures of the suitable nitrogen bacteria were always used. The soil being free from the usual bacteria these had a fair chance, and the result was very successful, leguminous plants (clover, serradella, and peas), giving a fairly good crop even the first year of cultivation, and other crops grown on the land following leguminous crops so treated were considerably imnroved.

The weight per acre of the crops for the years 1916, 1917 and 1918, and for comparison, the usual crop per acre for light land, as given by the Encyclopædia Britannica, are as follows:

	——Annual Crops per Acre.——			Normal Crops per Acre for Good
	1916.	1917	1918.	Light Land.
Rye	very poor	17 bush.	26 bush.	......
Oats	15 bush.	22 bush.	32 bush.	45 bush.
Potatoes	less than 1 ton	5 tons	7 tons	10-15 tons
Clover (hay)	....	1.3 tons	2.8 tons (two crops per ann.)	2 tons

The figures for 1918 are from official returns, and are too favorable; those for 1916-1917 are based on estimates by an experienced farmer. Root crops other than potatoes will not grow at all, at least in the earlier years of cultivation.

The effects of cultivation on the peat are that in a year or two it breaks down into a black pulverizable mass, easily worked, drying up very quickly in summer, and after prolonged rain getting so wet as to be unworkable. If the winter is a wet one, no work at all may be done on the land from November to March, and sometimes well on into April. If not too wet, ploughing may be carried on as usual. It may be noted that the general level of the cultivated land sinks, in this case, to the extent of slightly more than a foot in the first 4 years.

Horses have a broad, flat shoe attached to their feet when working on this land, to prevent them from sinking.

In general it may be remarked that if it had been possible to apply larger dressings of artificial manure, the results would probably have been slightly more favorable. On the other hand the weather of 1918 was most favorable for cereals, and the 1918 rye crop was considered very good for this land. The varieties grown were usually specially selected for the work, the potatoes being of a specially hardy red-skinned variety (known as Professor Brunkman), and the oats being black moor oats, while the clover was also from seed specially selected for this land.

Small Holdings on Peat Lands.—From general observation, and from the opinion of small holders occupying portions of this land, it could not be recommended for small holdings. The difficulty of working during the winter months, the fact that on account of the impossibility of growing root crops proper rotation could not be arranged, the cost and labor of the necessary yearly applications of artificial manure, and the fact that cottages built actually on the land were damp and unhealthy, were all disadvantageous factors. On the other hand, land prepared as above after two years' growth of clover and fine grasses makes good summer grazing for cattle, and large tracts were leased by wealthier local farmers for this purpose.

Although before the war the Germans could obtain the labor of Russian Poles at a very cheap rate—the equivalent of 1s. per diem with very crude board and lodging—yet at the rents obtained on leasing it was calculated that it would take 80 years to pay the cost of draining, cultivation, etc. This work was, however, subsidized by the German Government in accordance with its general agricultural policy of developing all land in Germany to the greatest extent possible, and large sums of money were set aside every year for that purpose.

If the workmen employed on this land were paid a reasonable wage, the writer is of the opinion that peat lands reclamation on this system could only be profitable and advantageous under very exceptionable circumstances. It may roughly be said that it pays better in Germany to reclaim almost any other kind of waste land.

Afforestation of Peat Lands.—A large tract to the north of this moor had been afforested in the years 1885-7. This tract was partly sandy, and partly "deep" peat, and all the usual timber trees had been planted on both portions. The timber on the sandy portions had in general grown very well, but the immediately adjoining timber on the peat was of very poor quality. The only exception to this rule was in the case of birch trees, which seem to flourish equally well on either soil. The German authorities take advantage of this fact in planting wind breaks and ornamental trees on reclaimed land, these trees being almost invariably birch. Fruit trees grow on the reclaimed land, but cannot be said to flourish.

RECLAMATION OF LANDS WITH SANDY SUBSOIL AND OF DEFORESTED LANDS.

Preliminary.—Portions of the moor on which the writer was directly engaged, and the whole of the immediate neighborhood, consist of sand mixed with coarse gravel, and a large amount of this land had been forest land; practically the whole land of the district having been reclaimed and settled within the last fifty years.

Drainage.—Where drainage is necessary the pipes need only be laid at a depth of 3 to 4 ft.; otherwise the methods of drainage are similar in every respect.

Cultivation.—The cultivation machine described in the foregoing sections was used for breaking the layer of heather and turf to a depth of about 4 in. This was immediately followed by ploughing in the ordinary manner. By ordinary methods of cultivation a good average yield was obtained by the third year. Small holdings and farms in general on this land show very much better results than the peat lands, and every kind of crop, including wheat and tobacco, was grown.

"Shallow" Peat Lands.

At Scharnebek, by Luneburg, in the valley of the Elbe, there is a large Government farm of about 700 acres. The soil here consists chiefly of black peat to a depth of about 12 in., and the land had formerly been afforested. Though large portions of this farm had only been under cultivation for three

years, yet on the occasion of the writer's visit in September, 1917, the whole of the crops could only be described as very good, potatoes, sugar beet, and Swede turnips showing exceedingly good results. The drainage on this farm had been carried out in the manner described, and certain fields had been covered to a depth of 8 in. with sand, apparently without improving the yield to an appreciable extent. The writer is unable, however, to give any figures relating to this estate.

Cultivation of Buckwheat on Peat Lands.

This is carried out as follows:—The land is first drained by open ditches every 20 yd., and the surface is then broken up into fairly large pieces—roughly 8 in. square. Formerly this was done by hand, but now by the "cultivator motor." As soon as the land is dry enough, usually about the early part of May, it is burnt, fires of the dry pieces of turf being lighted and spread broadcast. The whole surface of the land smoulders until the first shower of rain. The buckwheat is sown directly on this surface early in June, no other treatment being given to the land. The buckwheat ripens about the end of September, good crops being obtained.

THE RELATION OF HUMUS TO RICH SOILS.

By C. K. McClelland.

Nearly everyone understands what is meant by the terms "new ground" as used among us, or "virgin soil" as it is used in some sections. Of course the reference is to lands which have never been cropped, whose fertility has not been depleted by washing, by removal of crops, or through the oxidation of its substance under the good conditions given by tillage. What we know as humus is one of the important constituents of such a soil, and humus carries with it a considerable amount of nitrogenous matter, which, though in unavailable form, is easily released for benefit of crops when conditions for the changes needed are improved, as they are by the putting of this land into cultivation.

These soils usually represent the most fertile soils of a given section. They are formed in parts by the accumulation of vegetable matter for a number of years as a result of vegetable matter and the mixing of this and the roots of the plant with the soil. The leaves of the forest fall year after year, branches drop and partially decay, the tree itself dies and blows over, its roots which have penetrated deeply into the soil decay also; and with such life and death over a period of years there is made a soil that is rich in vegetable matter. On prairies, grass grows year after year and dies down in the fall, and here after a number of years we find an accumulation of the vegetable matter as accompaniment of good soil. In the swamps, we find a combination of grasses and shrubs and moisture-loving plants that, as they grow and decay, gradually fill up the low places and make rich soil. So we find that practically all of our better soils are the result of plant growth and death and the accumulation of the vegetable matter which is not entirely decayed.

We have, however, some soils that are fertile that seem not to come under the description we have given. There are some that are the result of the deposit by water or by wind of soil that is brought from other places, such as our bottom and delta soils and the loessial soils found in some sections; the soils deposited though contain a goodly amount of vegetable matter which has accumulated in the places whence they came, and they still come within our statement that rich soils usually carry goodly amounts of humus and nitrogen.

Just exactly what humus is no one can say, though some of its component parts have been identified and named by chemists. The definition generally given is that it is decaying vegetable matter in the soil—decaying and not de-

cayed, as then its transformations would be completed and its work done. It is made up of a number of different combinations in all of which the nitrogen is in insoluble form, and is the result of decay under conditions inimical to thorough decomposition. When the land is put into cultivation, better conditions for decay are provided and the humus is used up in a few years, faster in some regions than in others.

The conditions favoring the breaking up of humus or of any organic compound in the soil are plenty of air, heat, moisture and alkalinity, which favors the actions of the organisms assisting in the decay. Air may be excluded by water or in measure by the compactness of the soil; heat is not sufficient in cold wintry weather, moisture may be excessive or it may be lacking because of exposure to wind and sun; acidity, though sometimes high in swamp soils, usually is not high enough to interfere with the organisms in question.

Cold weather tends to check the loss of humus and to favor humus formation; on land that is in perennial meadow and undisturbed for several years there is a like effect. In the South, where we have no long winter season to help us nor yet any kind of grass suitable for perennial meadow, we are handicapped in the control of our humus; what material we turn over is soon decomposed. Probably more of the roots and stubble than of lot manure is used in true humus formation, but the vegetable matter, whether forming humus or not, gives us something of the benefits of humus in the betterment of the physical nature of our soils, the increase in water-holding capacity, and in the supply of nitrogen. We might say that humus in virgin soil is a bank account of long standing against which we draw, soon depleting the account, or reducing our "balance," while the vegetable matter we apply to soils under continuous cultivation is more like a merchant's capital that is turned over and over in business transactions—we keep adding vegetable matter to the soil and we continually are drawing it out, and we may never get back to virgin soil conditions.

Those of us who farm clay lands realize keenly the difference in ease of cultivation between our new lands and the old in which the supply of humus has been nearly exhausted; we know how the latter compacts and how difficult it is to plow unless taken before moisture is reduced to a low amount; we know that the old land does not contain the plant food that the new does, and that it will not produce as well, partly because of this lack of plant food or difference in the amounts of plant food and also partly because it will not hold sufficient

moisture to enable the plants to make their best growth. Those who farm sandy lands do not encounter the difficulties in cultivation of compactness of soil as the supply of humus is depleted, but they do find the difference in fertility and water-holding power.

All of us then are interested in the returning of vegetable matter to our soils; we have most of us learned better than to burn our old cotton or corn stalks or other crop residues, unless necessary for control of some pest, but will suffer what little inconvenience these give us in early cultivations; we save our straw after thrashing and use it as litter in the stables or lots to help save the manure, and we believe that it pays occasionally to plow under a crop to help in the holding up of the organic content of our soils. Some believe heavy fertilization, as it gives more stalk to turn under, is a means of holding up this supply of organic matter in the soil, and of course the larger the stalks the more is turned under; but unless complete fertilizers are used, the soil may be made poorer in other elements of plant food. Some men never mow their peas, but pick the pods and turn under the vines; nearly all plant peas or beans in the corn to secure as much material as they possibly can to turn under. The value of these practices is pretty generally recognized, and those who employ them and follow out this idea of returning all they possibly can to the soil are our best farmers and not soil-robbers in any sense of the word—they do not intend to enrich themselves by leaving a poor soil to their children.—(From The Progressive Farmer.

SOIL BACTERIA.

At the Chemical Industry Club, Newcastle, England, last November, the second of a series of meetings under the Technical Section was held under the presidency of Mr. O. Smalley. A paper on "Soil Bacteria" was read by Mr. F. H. Walker, B. Sc., A. I. C.

Mr. Walker commenced with a short resume of the progress of agricultural chemistry up to about 1860, when it almost came to a standstill, when the theories of Leibig on the mineral constituents absorbed by plants from manures had been found to be only partially true. Leibig, as they know, maintained that ammonia and not gaseous nitrogen was taken up by plants. After a great controversy, the experiments of Lawes, Gilbert, and Pugh proved that all non-leguminous crops thrived when treated under proper conditions with nitrogenous fertilizers and died when deprived entirely of combined nitrogen, despite the other mineral constituents being present. It was found that peas and clover could thrive without nitrogenous manure and the soil in which they grew actually became richer in nitrogen, and the amount brought down by rain failed to account for it at all. Thanks to Pasteur, the science of bacteriology made rapid progress. Pasteur appeared to have recognized that the change of ammonia to nitrate in soil was a bacterial process.

In 1887 Schloesing and Muntz remarked that when a stream of sewage was allowed to trickle down a column after a lapse of 20 days the ammonia in the sewage began to convert to nitrate and finally was completely converted. The process of conversion was stopped by adding an antiseptic and could be restarted by an addition of turbid water extract of dry soil. The "nitrification" was due to bacteria. Later experiments showed that nitrification took place in two stages and that there were two organisms. Beijerinck eventually isolated B. radicicola, and the conclusion was generally accepted that bacteria are the real makers of plant food in the soil.

After discussing the value of farmyard manure from a bacterial standpoint. Mr. Walker stated that he considered that acidity in soils might be caused by the prolonged use of sulphate of ammonia when not properly corrected by lime. In rich soils the bacteria might be greatly reduced in number by protozoa. B. radicicola could not live in acid soils or in land rich in nitrates, and Bottomley had finally selected peat as a suitable material for distribution. Raw peat was treated

with steam and afterwards inoculation with a mixed culture of B. radicicola and azobacter chroococcium, and remarkable successes were obtained. He described many of the experiments of Bottomley and Rosenheim at this stage of the paper. The attempt to put bacterized peat on the market as humogen had not been altogether successful. He described in detail many experiments which had been carried out with succcess in producing increased yields of crops.

A long and informal discussion took place, to which the Chairman and Messrs. H. Dunford Smith, G. Weyman, W. D. Jones, J. T. Carr, and C. S. Haddon contributed some remarks.

Mr. Walker, replying to the discussion, said that soil inoculation would not make up for bad cultivation or the shortage of certain material constituents. The weather had an enormous influence, and many of his own experiments had been inconclusive owing to the excessive drought. The bacterized peat could be used either with or without stable manure.

THE PEAT ENGINEERING COMPANY.

The Peat Engineering Company has been organized at Bangor, Me., to conduct a general engineering business. The capital stock is $500,000.

The incorporators are William S. Southard, president; Charles E. Pendleton, treasurer; H. J. Chapman, clerk; Fred T. Dow, Victor Brett, O. F. Files and John T. Clark, all of Bangor.

The primary purpose of this corporation is to develop a process for manufacturing peat fuel worked out by Fred T. Dow, a civil engineer and surveyor of Bangor, Me.

The process in question is briefly described as that of a hot air blast drying machine connected with a moulding press, delivering the peat in cylindrical form.

Such cylindrical blocks of peat, about 4 inches long and 1½ inches in diameter, were made on a small scale some time last year at a plant at Old Town, Me.

NEW JERSEY PEAT INDUSTRY IN 1918.

Statistics compiled by the Department of Conservation and Development of New Jersey, giving the mineral production of that state for 1918, state that this state stands first in the union in the production of peat.

During the year 1918 there were produced 26,218 tons of peat valued at $264,822.

CANADIAN PEAT PROJECT INDORSED.

It is reported from Ottawa that the members of the joint federal and provincial peat committee, which has been conducting an investigation of experiments at the Alfred peat beds, near Ottawa, are satisfied that peat can be sold for commercial purposes as an auxiliary to coal. Hon. Edward Ferguson, minister of lands, forests and mines for Ontario, has announced that peat can be supplied at $3.50 per ton f. o. b. point of manufacture. It is then compressed into briquettes and dried for fuel. Steps are to be taken to induce municipal authorities to introduce peat this winter.

IRISH RECONSTRUCTION.

A report has just been issued by the Joint Council of Executive Professions on questions appertaining to Irish reconstruction. Recommendations deal with housing, electric power schemes, reconstruction of roads, and the Government is urged to proceed with schemes of arterial drainage, with the object of utilizing the bogs and waste lands of Ireland to the best advantage. Two simple experiments, it is pointed out, surface drainage for agricultural reclamation and bottom drainage for fuel supply, if made on a sufficiently large scale, and over a sufficient length of time, will determine whether the 3,000,000 acres of Irish bog land is available for agriculture, and whether the 3,000,000 tons of coal-equivalent is available for fuel purposes, for domestic uses and power, in competition with or substitution for coal. The considerable number of water powers distributed all over the country, it is asserted, if worked in conjunction with one or more electric power stations, so as to use the full power at any time available, would be in the aggregate of very great value. They recommend that the vital problem of cheap power should be entrusted to a strong body of business and professional men.—(The Colliery Guardian, 1919, Vol. 118, p. 1112.)

IRISH PEAT.

In his presidential address recently delivered before the Institution of Civil Engineers, Sir John Purser Griffiths referred to the work of the Committee of Enquiry into the utilization of Irish peat deposits, set up by the Fuel Research Board, of which he is chairman. He said the valuable work of the Bogs Commission had been shelved for more than 100 years, but, fortunately, its reports and maps have been carefully preserved in the archives of the Royal Dublin Society and the National Library of Ireland.

Very large areas of Ireland are covered by its bogs, estimated to amount to about 3,000,000 acres, more than one-half of which are "Red Bog" as distinct from "mountain peat soil." More than 1,000,000 acres of these bogs represent the flat and deep bogs, three-quarters of which are concentrated within the central belt, bounded on the north by a line joining Howth with Sligo, and on the south by a line joining Wicklow with Galway. It is estimated that the Irish bogs contain between 3,500,000,000 tons and 4,000,000,000 tons of anhydrous peat, or 5,000,000,000 tons of air-dried peat.

At present, about 6,000,000 tons of peat per annum are

burned as fuel in Ireland, and over 4,500,000 tons of coal are imported. If this coal were replaced by peat fuel at the rate of two tons of air-dried peat to one ton of coal, requiring about 9,000,000 tons of air-dried peat, the total consumption of peat in Ireland would be about 15,000,000 tons per annum, and the peat deposits would be sufficient to satisfy the fuel and power requirements of the country at the present rate of consumption for more than 300 years.

The Irish Peat Committee devoted much time and thought to the subject referred to them, and came to the conclusion that the reclamation of the bogs for agricultural purposes could be successfully combined with the winning of peat for fuel, but that the introduction of mechanical winning and handling was essential. The reports of the Irish Peat Committee, together with the report upon them by the Fuel Research Board, have been in the hands of the Government since September, 1918, and nothing further has been heard of them. They now lie buried in some Government pigeon hole.

Sir John Purser Griffiths said it was not economy to allow our peat bogs to remain undrained and unreclaimed, when they might become a source of national wealth in food and fuel. It was not economy to allow our water power resources to run to waste, instead of using them to reduce our coal consumption, and delay the day, which is not far distant, when our coal supplies would be exhausted or unavailable, either by consumption or the increased difficulty of winning. He thought they should look the approaching exhaustion of our coal supply fully in the face; and the development of our peat and water power resources was an urgent and pressing need. Neither of these great problems could be dealt with unless the State took action and removed the obstacles which excluded the possibility of private development.—(The Colliery Guardian, 1919, Vol. 118, p. 1374.)

PEAT FUEL IN DENMARK.

There are deposits of peat in various sections of Jutland (the continental portion of Denmark), and on the different islands. The total peat area has been estimated at 62,000 square miles. If an amount of peat were used annually equivalent to the heat value of 4,000,000 tons of bituminous coal, this supply would meet all of Denmark's fuel requirements for about 37 years. The lack of coal stimulated peat production, and 397,800 tons were produced in 1917, as compared with 285,000 tons in 1916.

Two tons of dried and prepared peat have approximately the same heat value as one ton of ordinary coal. However, peat is so bulky that it is difficult and wasteful to handle, and even though the original cost of peat is less than coal the final cost, after handling, is about the same as that of imported coal.

Peat has been used principally for domestic heating purposes, but also to some extent in industrial plants and as locomotive fuel. In many places the gas plants have been experimenting with peat in producing illuminating gas, but the consumption for this use has not been large. If the use of peat by the gas plants is developed to any extent, the production of coal-tar products, ammonia, etc., will undoubtedly form valuable by-products.

About a year ago the Danish Government fixed a maximum of peat at $7 per ton at the moor and $8.60 per ton loaded in freight cars f. o. b. the seller's nearest railway station. The Government has done all in its power to encourage the production of peat and has given some financial assistance in the farm loans at low interest rates to producers. In 1917 there were in operation over 200 peat works that were partially supported by the Government.

The following figures show the output and number of factories producing machine-made peat in Denmark for certain years, the sudden increase for 1916 and 1917 being due to efforts to replace the usual supply of imported coal shut out by the war:

Year	Factories Number	Output Tons	Year	Factories Number	Output Tons
1902	39	46,760	1915	99	95,145
1907	53	63,948	1916	204	285,000
1912	90	84,788	1917	747	397,846
1914	97	86,849			

The results obtained from peat fuel have been far from

satisfactory. The large increase in peat production has been due chiefly to price-fixing by the Government and to other aid extended. These measures were taken, of course, to provide fuel for the country in emergency, and when coal at a lower price and in sufficient quantities is again on the market the peat production will undoubtedly go back to its old basis. —(Consular Report.)

KAURI-GUM EXTRACTION.

The kauri-gum industry experienced a very depressing year during 1918 owing to a shortage of gum diggers and the difficulty in securing shipping space to export the small supplies. The exports for 1918 were valued at $765,564, as compared with $1,651,413 for 1916, and $2,420,811 for 1914; which means that the actual exports dropped very much below normal, since prices were higher than formerly. Prospects for 1919 are not promising, for a large number of the gum diggers have been set to work on the railways and other Government construction work.

A new branch of industry is being opened up by way of extracting kauri oil from the kauri-gum peat taken from the swamps where large quantities of decayed gum are found mixed with the soil, or in some places, almost solid beds of shale gum. It is claimed that there are areas from which kauri oil may be extracted to the value of $121,663 per acre. A company is now manufacturing 100 barrels per week, and proposes to enlarge the plant as soon as possible. About 15 per cent of the oil can be easily turned to motor spirit, about 15 per cent to an oil used in working up india rubber, about 30 per cent in paint oil, the same amount in varnish oil, and the remainder in pitch. It is expected this industry will become an important factor in the Auckland province.—Consular Report.)

MOLD FOR PEAT.

F. T. Warburton (Can. Pat. 185,294).

This patent describes a group of peat molds, which are mounted on a car, above which is suspended a receptacle for peat pulp. The receptacle holding the peat is movable and so mounted that it can be moved easily over the top of all the molds on the car. The molds are filled from this receptacle. Each mold is provided with a retaining plate having a handle so that the same can be withdrawn. The side plates of the

mold are secured by clasps. The molds are arranged independently so that each one can be transferred to a place of drying and discharging without interfering with any other molds on the cars.

PEAT DRIER.

W. H. Jackson (Can. Pat. 185,779).

This peat-drying machine is a steam-heated cylinder lying in a horizontal position and provided with hopper for feeding the wet peat into the same. Through the center of this cylinder passes a hollow shaft, held in bearings outside of the cylinder, with proper provisiosn for rotating the same. A tubular worm is arranged within the cylinder and has its end connected to the hollow shaft. A supply of steam passes through the hollow shaft and the tubular worm. The tubular worm is secured to the shaft by radial agitators or spiders so that when the hollow shaft revolves both the tubular worm and spiders revolve and convey the peat through the drier.

PEAT-CUTTING MACHINE.

E. A. Persson (Can. Pat. 187,496).

The machine is suspended between two cars, the cars traveling upon parallel tracks. On the one track is a motor car and on the second track, which is a substantial distance from the first named track and parallel with the same, is a stationary car. The stationary car contains the machinery operating the plow shaft which is connected to a transverse bar between the two cars. The machinery on the second car is operated by a belt from the motor car. There is a frame between the two cars which has a number of plow shafts operating in the same direction as the cars run. This frame, which rests on the transverse bar, can be easily detached from the cars on the track and wheeled away.

EXPRESSING WATER FROM PEAT.

J. W. Hinchley (Can. Pat. 190,766).

This patent describes a process of subjecting the peat, primarily at ordinary temperature, to an evenly distributed temperature. The second step of the process admits hot gases to this prepared peat and then subjecting the peat to a higher degree of pressure. The liquid separated in this process is forced through strainers and liquid is also forced down the back of the strainers to prevent the same from being choked.

PEAT MANUFACTURE.

Charles Bouillon (Can. Pat. 191,345).

This invention is similar to the British Patent 118,993 (see this Journal, Volume 12, page 102). It is essentially the separation of the fibrous peat from the non-fibrous material. The peat is treated in a coagulating tank, after it has been dried and crushed, so that it is easily disintegrated in the solution contained in the tank. The tank is provided with proper machinery for carrying the peat through the same. The tank is connected with a revolving sieve which collects the vegetable fibers, passing them to a washer and a collector, where the fibrous material is passed on.

PEAT TREATMENT FOR INDUSTRIAL PURPOSES.

J. A. Oligny (Can. Pat. 194,828).

This invention discloses a process for producing a peat suitable for industrial purposes. The process comprises the saturation of the peat with a brine solution. The solution can be of common salt or chloride of calcium. The peat is immersed in its native state in this solution and the solution is then electrolyzed. It is claimed that this electrolysis first decomposes the elements of the solution and finally assists in the saturation of the peat, producing a mixture of the peat with filler and thus creating a more resistent body in its dried state.

FIRING WITH PULVERIZED PEAT AND THE LIKE.

C. A. Westerberg (Br. Pat. 117,265).

This invention relates to improvements in firing with pulverized fuel, such as coal or coke breeze or powder, saw-dust, peat powder, etc. It has been proposed to inject into a furnace, by means of an air blast, pulverulent fuel and gas. The invention consists in burning a gaseous fuel in a furnace and blowing the powder fuel into the flame of the gaseous fuel, the powdered fuel being introduced by means of an air blast which opens into a receptacle for the powdered fuel and induces the inflow of the gaseous fuel. By these means an effective and complete combustion is effected even in those cases where the powdered fuel cannot maintain combustion of itself, which occurs, for instance, with charcoal breeze. Such a fuel therefore cannot be burnt in the same manner as, for instance, peat powder, but its combustion can be obtained

according to the present invention. The gaseous fuel may be of different kinds, but it is perferred to use blast-furnace gas when such a gas is accessible. A blast pipe may be provided for the supply of air for combustion opening into a receptacle for the powdered fuel, the receptacle being furnished with a connection for a gas supply pipe. A supply pipe may be arranged for compressed air or steam, said pipe opening beyond a feed wheel arranged in the lower part of the receptacle for the powdered fuel.

FEEDING DEVICES FOR PULVERULENT FUEL.

Motala Verkstad Nye Aktiebolag (Br. Pat. 118,100).

This invention relates to feeding devices for pulverulent fuel into furnaces (for example, of locomotives and other engines), of the kind comprising a receptacle into which projects one or more air or other gas admission conduits, and one or more pipes for conveying the fuel to the furnace, the ends of the air conduits and fuel pipes being immersed in the powder and located adjacent each other, whereby powder is entrained by the air or gas into the fuel pipe, or pipes, and thence to the furnace. According to the chief feature of this invention, in addition to discharge opening or openings for directing air or gas jets into the powder so as to whirl it up, there are provided one or more air openings through which air flows directly into the inlet of the fuel pipe for the purpose of assisting by this injector action the transport of the mixture of air and powder through the fuel pipe, the control of the supply of air to the latter openings and the former ones being effected by one and the same member. The flow of air or gas may be maintained by the furnace draught with or without the assistance of a blower. Steam may also be used as an entraining agent.

PEAT FUEL.

C. M. C. Hughes (Br. Pat. 127,024).

Fuel is made from waste carbonaceous materials such as house refuse, destructor ash, coal or coke dust, sawdust, peat, etc., by the addition of a small quantity of a hydrocarbon such as pitch, or a carbohydrate such as molasses or glucose, together with soot or charcoal, in the proportion of 4 parts of soot to 8 of the hydrocarbon or 10 of the carbohydrate. The fuel is molded without pressure and then broken into pieces. Other materials such as chalk, salt, or creosote

oil may be added, and if the waste carbanaceous materials are poor in oxygen, they may be treated with a solution of potassium chlorate or permanganate. In one method of making the fuel, the materials other than the creosote oil are first dried and mixed together and then added to the creosote oil in a heated cauldron. The temperature is raised to 240° F., the mixture being then poured into tanks greased inside or painted with a solution of lime in water. After solidifying, the block is turned out and broken up.

REMOVING WATER FROM PEAT.

A. T. Bosch (Br. Pat. 128,064).

Peat, etc., placed in high towers so that it is compressed by its own weight, is treated first with hot water and afterwards with steam to reduce the water content. The upper part of the tower is narrower than the lower part, which is fitted with a grid. Peat is fed in through the hopper and the slide is closed. After free water has drained away, hot water from an adjacent tower is admitted through a pipe and afterwards steam is supplied to channels communicating with the interior of the tower and also through a pipe to a perforated nozzle extending upwards into the peat. Water drains away through a pipe and is delivered by a pump to the next tower. The slides are then opened and the peat discharges through the outlets.

DESTRUCTIVE DISTILLATION OF PEAT AND SIMILAR CARBONACEOUS MATERIALS.

P. Moore (Br. Pat. 131,006).

This invention relates to the distillation of wood, woody fiber, peat and similar carbonaceous substances, and has for its object to improve the yield of by-products and particularly of acetic acid and wood spirit, while reducing the period of distillation and generally securing economy and efficiency in the process. According to the inventor the wood or other carbonaceous substances in small pieces or in a finely divided condition is dried, whereby its content of water is substantially reduced, and the dried raw material is then distilled within a retort to which heat is externally applied; and after the charge is uniformly heated to such a degree that condensation of steam within the charge is precluded superheated steam is caused continuously to pass through the charge, and the heating is continued. The gas and vapors evolved from

the charge pass out of the retort for the recovery of the condensates.

FUEL COMPOSITION.

C. Gonville (Br. Pat. 132,418).

This invention has for its object the production of a fuel adapted to replace the coal or coke at present used for generating steam or for heating purposes, and it consists in the utilization of the pitch and coke breeze which constitute by-products in gas making, to form, with the addition of other ingredients, a cheap and efficient fuel adapted to wholly or partially replace the coal or coke at present used in manufactures or for household purposes. To this end the invention consists of a fuel constituted by the following ingredients in substantially the proportions mentioned, viz: Pitch, 30 per cent; coke breeze, 20 per cent; peat, 40 per cent; sawdust, 5 per cent; coal dust, 5 per cent. The inventor manufactures the fuel by incorporating the pitch, while in a hot state, with the other ingredients in a mixer, preferably heated (either by steam or gas), and fitted with a mechanical stirrer (and, if necessary, provided with an Archimendean screw device), which serves to produce a homogenous mass which, when removed from the mixer, is pressed by hydraulic or the like means and cut into blocks of suitable size. This will produce a fuel which is cheap and which possesses the heating power required, and which enables a large proportion of the by-products which at present encumber the works of the gas companies and are practically wasted, to be made use of.

DECOLORIZING AGENT.

J. W. Leadbeater (Br. Pat. 132,572).

This invention relates to the treatment of peat to obtain a carbonaceous material for decolorizing sugar solutions, oils, waxes, etc. The peat is dried, ground, mixed with ground quicklime, carbonized on trays in a retort or oven, and then washed with a solution of hydrocloric or other acid as described in Specification 122,698. The washed material is mixed with fuller's earth, hydrated aluminium silicate, kieselguhr, diatomite, or other infusorial earth containing nearly pure silica, and is then heated or dried in an oven or retort.

BRIQUETTING OF PEAT.

E. G. Lea (Br. Pat. 133,847).

Many attempts have been made to produce a satisfactory fuel by briquetting air-dried or artificially dried peat in a briquetting machine of the ram type. The inventor's experiments in this direction have shown that two conditions are essential for the production of good, hard, dense and durable briquettes in a machine of the said type. In the first place the disintegrated peat fed to the machine should contain not more than 35 and not less than 20 per cent by weight of water, preferably between 20 and 30 per cent; secondly, the temperature of the peat should be between 125° F. and 175° F. If the first condition is not observed the briquet, if the water content exceeds 35 per cent, will be relatively soft and spongy, and will crack and break up on storage and in handling; while if the water content is much less than 20 per cent, the briquet will lack cohesion and the finer particles will fall and rub off from the exposed surface to an excessive extent. The second condition is essential for the proper utilization of the building qualities of the resinoid constituents of the peat, to which are due in great measure the durability of the briquet, its desirable smooth, glossy surface, and its resistance to the disintegrating effect of variations of atmospheric humidity and temperature when stored. According to this invention, the peat which has been air dried and disintegrated is further dried, if necessary, to reduce its content to between 20 per cent and 35 per cent by weight, and is then pressed in a briquetting press of the ram type, preferably at a pressure of 2/5 ton per sq. in., while its temperature is between 125° F. and 175° F. The most convenient method of insuring this temperature during the compression is to heat the peat while completing the drying, if necessary, before it is charged into the press, to a temperature which will insure that within the press it has the essential temperature. For example, the peat is cut in blocks which are stacked under conditions suitable for air drying, which is allowed to proceed until the blocks break readily along the direction of the bulk of the peat fibers, and not, as when wet, almost as readily in any plane. The air-dried blocks are then disintegrated in a disintegrator which, when fibrous peat is under treatment, fulfills the aforesaid conditions as far as possible; the bar type of disintegrator has been found useful. The degree of disintegration should preferably be such that the pieces are not much larger than ½ cu. in. in volume. The disintegrated peat in a suitable plant, which in

most cases should also be capable of drying the peat to the desired content of water, and is fed into the press while its temperature is at or below 175° F., but so that its temperature in the press shall not be below 125° F.

PEAT COKE FOR THE RECOVERY OF GASEOUS PRODUCTS.

E. Bury, O. Ollander and A. E. Bury (Br. Pat. 133,159).

A peat coke prepared at 700°-900° C. is used as a cheap but efficient substitute for wood charcoal as an occluding agent for the selective separation of gaseous products from carbonization processes. The coke is soft and loose, and readily allows the passage of gas through it. The absorbed gases are removed by the application of heat, and the coke is returned to the absorption vessel for further use.

EXCAVATING AND HANDLING PEAT.

J. M. Shuttleworth (Br. Pat. 133,512).

This invention relates to improvements in a system of handling peat, and the object is to provide a continuous system for economically cutting, spreading, piling or cubing, and stacking the peat in form convenient for loading into transport vehicles. A further object is to provide a system which may be operated at a minimum of cost and with a minimum of labor. A still further object is to provide a system which may be carried out with a minimum amount of simple and rugged machinery. According to this invention, the working area is preferably laid out with a view to obtaining a maximum length, so that the apparatus may travel for long periods of time in one direction (a minimum of one day being preferred), without loss of time in reversing. The excavator and macerator are preferably located on a single platform which is mounted on endless traveling tracks. The whole arrangement is provided with a reversible drive, so that it may travel up and down along a working face without any time being lost in turning the apparatus around. A bridgework extends from the platform at right angles to the direction of travel, and is supported at its outer end on an endless traveling track which is driven by a shaft extending through the bridge. This bridge supports an endless conveyor and draws at any point throughout its length a peat-spreading apparatus. At the outer end of the conveyor is a dry peat stacking elevator.

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Mr. Chas. Knap, Secretary,
American Peat Society,
17 Battery Place,
New York, City.

Dear Sir:—

I, the undersigned, being interested in the development of our peat resources and in the welfare of the peat Society, beg to make application to membership in your Society, for which I enclose $5.00 as annual dues.

Signed ....

Address ....

....

CONTENTS

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NOTE.

The publication of articles in the Journal of the American Peat Society is not an endorsement of the same by the Society or its officers. The American Peat Society is not responsible for the statements and opinions advanced by authors or correspondents. Written discussions on articles appearing in the Journal are invited. Correpondents and articles regarding peat and cognate subjects solicited.

LOGICAL METHODS OF UTILIZATION OF MINNESOTA PEAT.

In our last Issue (Jan. 1920) an article under the same heading represents a paper by Mr. Henry H. Hindshaw of Hibbing, Minn. There appears on page 40 of that Issue a citation from The Canadian Department of Mines on recovery of the nitrogen in the peat as ammonium sulphate. The quantity of 26,000 tons per year from a hundred ton plant, with a peat containing 2½ per cent nitrogen, is an error, which escaped our attention at the time of publication and should have read 2,600 tons of sulphate. HERBERT PHILIPP.

PEAT CLASSIFICATION.

To the ordinary layman, anything that is called "peat," is interpreted as a possible source of fuel. To the agriculturist, muck, humus, marsh, fen, bog, heath and swamp are terms used generally referring to peat lands; these terms generally refer to the well-marked physiognomy of vegetation appearing on the peat deposit and have no significance whatsoever to the type of peat material existing in the deposit. No serious attempt has been made in this country to properly classify our various deposits. Since the better understanding of the uses of our peat deposits now exist, endeavors should be made to properly classify and standardize, as far as practicable, the various peats forming the deposits.

Anyone who studies various peat deposits can easily realize the importance of a definite classification so as to very materially assist in determining the possible agricultural and industrial uses to which peat can be put. The chemical analysis of a peat deposit is by no means a final test on the best uses a peat can be utilized for, in fact the botanical and physical characteristics of a peat should precede a chemical analysis in figuring out the best economical use of a peat.

The chemical analysis of a peat is only a final step in solving a peat problem and the classification of peat must be founded on the origin of the botanical decomposition which will be seen to be the prime factor in determining the classification of any peat deposit.

The next important factor governing the classification is the texture of the peat which also determines the degree of decomposition which peat has undergone, whilst the third and last important point is the color which generally varies according to the degree of decomposition and the character of plant remain forming the organic material. A chemical analysis can only be considered as a supplement to the above factors, when the usefulness of a peat for industrial or agricultural purposes has come under consideration.

There are several more factors covering the classification which are well set forth by Alfred P. Dachnowski, of the U. S. Bureau of Plant Industry. We reprint in this Issue his Bulletin entitled "Quality and Value of Important Types of Peat Material," and would draw this to the attention of any seriously minded peat workers, who will find there a fund of collected information, concisely put together and it offers much food for thought. The matter brought up in this article is of considerable importance to the economic develop-

ment of our peat resources and every reader is invited to correspond with the editor on the subject, because it is our idea that the American Peat Society should lead in establishing a standard classification of peats and every reader is requested to give this matter time, and to take an active participation in attempting a standard classification to fit the types of peat material existing in the North American Continent.

Now we do not want you to read this and pass it by without communicating with the editor that you are interested enough to assist the Society in this big work. Drop us a line that you are in on the ground floor of the peat classification section. For such work you will earn the deepest gratitude of our present and future generations.

HERBERT PHILIPP.

PEAT BOG FIRE EXTINGUISHING INVESTIGATION.

U. S. Bureau of Mines.

In October* 1919 we reported that State forester W. T. Cox of Minnesota was endeavoring to determine, together with officials of the U. S. Bureau of Mines, methods of preventing serious forest fires emanating from peat fires by effectually fighting the peat fires. Mr. Cox addressed the following letter to the U. S. Bureau of Mines on August 14, 1919 as follows:

"We are very much interested in the suppression of bog or peat fires in Minnesota. These smoldering fires in peat lands do immense damage in themselves through destroying valuable meadows and other property, and very often give rise to serious forest fires. The fires of last October, in which over four hundred people lost their lives, were in large part caused by peat fires coming to the surface during a high wind, and thus forming surface fires with wide fronts. The forest rangers are frequently called upon to combat peat fires, and the fighting of such fires is not satisfactory, because it is so difficult to dig them out. The work is slow and exceedingly expensive; moreover, it is difficult to tell when the fire is actually out.

"It has occurred to me that perhaps some of the fire extinguishing gases, with which you have been experimenting, may be serviceable in putting out peat fires. The matter is of such importance that I feel it would be well worth while

*See this Journal. Volume 12, page 215.

for your Bureau to send a man up here to cooperate with us on experiments along these lines. At the present time we have rangers working on peat fires, and we should be very glad to try out any gas you may recommend. The time for such experiments is in the early fall. We have millions of acres of peat in this State, and of course we do not want it all burned up. It is important also that some way be found to prevent peat fires from smoldering until conditions make them dangerous to the whole surrounding country. If you can devise some way for extinguishing fires in peat more cheaply than the present method of digging them out, I feel that you will be helping to solve an exceedingly important problem."

Mr. O. P. Hood, Acting Director of the Bureau of Mines replied to Mr. Cox, on August 19, as follows:

"In reply to your letter of August 14, concerning peat fires in Minnesota:

"The Bureau has made an extensive investigation of underground coal and metal mine fires and of spontaneous ignition of coal storage piles. While your problem is somewhat different it is possible that the experience of the Bureau will be of value to you.

"The District Engineer of the Bureau for Wisconsin, Michigan and Minnesota is Mr. B. O. Pickard, headquarters, Ironwood, Michigan, but who can be addressed at the present time at Houghton, Michigan. Mr. Pickard is a man of considerable and varied experience in fighting and controlling underground fires. I am instructing him to get into communication with you and he will, no doubt, be able to confer with you in St. Paul in the near future."

In accordance with instructions, Mr. Byron O. Pickard, District Mining Engineer of the U. S. Bureau of Mines, with headquarters at Houghton, Michigan, had a conference with Mr. W. T. Cox, State Forester for the State of Minnesota, in St. Paul, on September 17, 1919. The U. S. Bureau of Mines have very kindly placed Mr. Pickard's report at our disposal which follows below.

B. O. PICKARD'S REPORT.

We weighed carefully the matter of using gas or gases in extinguishing large fires, but both practically agreed that such a method would not have any practical value. It appears that the peat itself contains enough oxygen to support combustion, even if entirely isolated from the atmosphere.

I told Mr. Cox that I have never thought much about the matter, neither had I ever looked into any peat bogs, but

upon my next visit to the Cuyuna Range, I would stop off at Cloquet and visit their forest experiment station and discuss the matter with their Mr. Kenety, Supervisor.

It appears to me that if the Bureau can develop some method for the quick extinguishing of peat bog fires it would be doing a great service to the country at large, and also save the peat for future use.

Mr. Cox also suggested that a visit be made to the Warroad sections in Minnesota, and an investigation made of one or two of the larger peat bogs, in company with Mr. E. A. Linder, District Ranger for the State of Minnesota, as Mr. Linder is considered the best informed man on peat bogs, and is the most experienced peat bog fire fighter in the employ of the state.

On October 10 and 11 the writer went to Warroad and was met by Mr. Linder, who treated him very courteously and made conditions agreeable whereby two large peat bogs were investigated. One of these peat bogs had been partially burned about two years previous. The other has never been burned. This district is in the vicinity of the Lake of the Woods. In its original state it was no doubt very swampy, and now several hundred thousand acres are covered with peat bogs, or peat deposits, in which the peat will vary from two to twenty feet in thickness, with an average of from six to seven feet.

Recently the State of Minnesota has drained several hundred sections of this swamp by means of an extensive system of drained ditches, so that a portion of this original swamp land has been reclaimed for farming, and an excellent opportunity of studying the peat formations is offered. The peat, of course, lies on the surface, and in this district is underlain by clay, sand, etc. The peat seems to be an exceptionally pure variety, there being very little sand or soil mixed with it.

Two samples of the unburned bogs were taken, and have been expressed to the Pittsburgh office, attention Mr. Fiedner, for such future tests as may be deemed advisable by the Bureau.

During the summer months, the rank growth of wire grass and other native grasses occurs on the surface of the peat. This grass dries in the fall and becomes easily inflammable, especially if the fall season is dry. Peat formations, once catching fire, have been known to burn for several months; in fact fires started in the fall are apt to burn all through the winter season, regardless of rain or snow fall. Fire lines are often ten miles in length and very frequently

average from five to six miles. The peat being very porous is dried very quickly by the heat of the fire, tending to make it more inflammable.

CAUSES: The fires are started through the following agencies, arranged in the order of their importance:

1. Farmers clearing land by burning.
2. Railroad trains.
3. Cigarettes and matches from pedestrains and automobiles.
4. Camp fires left burning.
5. Lightning.
6. Spontaneous combustion, etc.

It is the general opinion that the surface burns and the fire slowly eats its way downward, water and snow forming an insulating crust, which tends to keep sufficient heat in the formation itself to carry on slow burning, until the bog formation is exhausted.

The writer is informed that the only successful means known today of fighting peat bog fire, is to dig a wide trench ahead of the fire the entire length of the fire line, and of course, ahead of the wind. The ditch must be wide enough to prevent the fire from jumping.

To dig a ditch in peat is more difficult than it sounds, as the peat is very resistant to shoveling, as a result it is very hard, slow and tedious work. Also as the ditch must be dug ahead of the wind, the shovelers have to work in smoke and gas. Plows have been used successfully in this work. Where water in large quantities is available, flooding has been used successfully.

As to using fire extinguishing gases, the writer does not believe the idea is a practical one, for the reason that at best only the surface of the peat formation would be affected; that is, the gas could not be kept on the surface long enough or in sufficient concentration to attack the fire in the middle or lower portions. Also the expense of using fire extinguishing gases would be prohibitive, and the writer does not know of any method whereby the gases could be discharged over large areas in sufficient concentration to replace the oxygen content sufficiently to prevent combustion. Even if it were possible to use such gases, it would be dangerous to the people and animals in the immediate vicinity.

If the fires were not of such large extent it might be possible to use chemical fire extinguishers, but unfortunately the fires in a peat bog spread rapidly, and often times are not accessible.

Mr. Linder is of the opinion that the only practical way to fight a peat fire is with a ditch, such as described previously, or by flooding, when water is available. In this opinion the writer concurs. (Signed Byron O. Pickard.)

Editors Remarks.

We have frequently, very frankly, expressed our opinions, both by pen and word, of the disastrous effect of peat fires. Peat fires are not only a menace to the surrounding community, but are a wasteful destruction of a mineral resource.

The method described by P. O. Pickard is the only effectively known method of successfully combatting a burning peat bog, unless the deposits are so drained that they can be flooded at will.

Agriculturists frequently burn the top of a peat deposit with the idea of increasing the mineral content of the peat soil and also increasing the nitrogen content; nevertheless such work is disastrous to a conservation policy. It is true that the mineral content of the deposit surface is increased, it is also true that the nitrogen content is increased about 25 to 30 per cent, but the enormous loss of organic material and 70 to 75 per cent of the nitrogen content of the burnt peat constitutes a wilful destruction of nature's resources. It is hard to conceive that our civilized governments should tolerate the destruction of nature's valuable store house of riches which allow future generations to be robbed. It is just as much a mystery as why a man suffering from fuel shortage, might not burn up his furniture, then his inside trimmings and finally his house, to give him a temporary respite from the cold. State and federal laws exist which penalize the wilful destruction of man's handiwork, is it not just as important that we respect and govern the handiwork of our supreme power? HERBERT PHILIPP

Burned Peat Bog. Note Fallen Trees.

Same as Above.

Cross Section Drainage Ditch Bank, Showing 2½ Feet of Peat and 4 Feet of Clay.

Drainage ditch through peat. Peat varies from 2½ feet to 20 feet in this ditch. Note road built of peat excavated from this ditch.

General View of a Reclaimed Peat, Bog, Now Being Farmed for Hay.

Same as Above. Notice the Wire Grass Growing on the Surface.

ORIGIN OF COAL.

So much has been written on the geological formation of coal that the revival of the old Chesebrough theory, that coal is formed from natural gas products does not create as much interest as it did about fifty years ago.

It is very interesting to note that just as this theory is being revived a motion picture has been devised by Jerome Lachenbruch demonstrating by pictures the formation of coal from vegetable matter, adopting the theory held by the majority of geologists.

Heretofore, it has been impossible to give a graphic description of the slow formation of coal, but with the invention of the method of making animated cartoons, a way has been found to show the formation of coal. The animated technical drawing, similar in method to the animated cartoon is the result of making 1500 individual photographs on a roll film of as many separate drawings. These drawings have been made by artists of the Goldwyn-Bray studios from studies of coal deposits and of the way in which they are formed.

The picture first reveals some trees and other plant growths situated in a swamp near the mouth of a river. Then a descriptive title discloses that the woody fibre of decaying trees and other vegetable matter is transformed by the elimination of oxygen and hydrogen in proportionately larger quantities than carbon. Not only does the vegetable matter change its chemical properties, but also the mineral substances, which are gradually converted into composites similar to fireclay.

This transformation has been found to be caused by the presence of fungi and bacterial ferments. The decay of plant growth progresses most favorably when the river level rises and falls rather frequently. The reason for this is that the fungi help along the decay when the plant growths are in the air and the bacterial ferments do their work best when the plants are submerged.

The intermediate stage in the transformation of the forest into coal shows the woody substances transformed into a brown gelantinous mass which sinks into the earth. Very gradually, the percentage of carbon increases until it composes almost the entire mass.

The relationship between coal and plant growth has been traced through the presence of numerous forms of bacilli of coal seams which are identical with the types of bacilli found in trees buried under peat bogs. The same kind of bacilli

has also been found in wood fossilized by silica and carbonate of lime. In this way, scientists have been able to trace the history of coal through the ages.

All the various stages in the formation of the coal deposit may now been seen on the screen. The result is an intensely interesting and instructive picture which reveals the possibility of the screen to tell, by means of the animated technical drawing, the thousand and one wonderful facts of the universe which the dullness and intricacy of scientific books keeps from millions of people anxious to know about them in a simplified way.

A PHOSPHATE--HUNGRY PEAT SOIL*

By F. J. Alway.

Agricultural Experiment Station, University of Minnesota.

INTRODUCTION.

Experiments in European countries and in the United States and Canada would appear to have reduced the number of kinds of peat soil, classified according to the initial chemical requirements, to four, viz.: (1) those needing no chemical application, (2) those needing potash only (3) those needing potash and phosphate, (4) those needing lime, potash and phosphate and, except for inoculated legumes, nitrogen also. For Minnesota we must add a fifth class, this consisting of those needing phosphate only, at least for the first year or first few years after being brought under cultivation. It is not improbable that some instances of the last group have been met with in Sweden, but no experimental data on these appear to have been reported. The present article deals with such a peat, in which no sign of potash-hunger, commonly regarded as the most characteristic chemical feature of peat soils, appears even in the second year.

The experimental fields dealt with in this report were operated by the Minnesota agricultural experiment station under the terms of the following section of a general appropriation bill of the Minnesota legislature of 1917:

Sec. 13. For the leasing or otherwise securing for experimental purposes three tracts of land having a peat soil, the same to be not less than 10 acres nor more than 40 acres; one situated in Beltrami county or some county west

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of it, another in Itasca or Aitkin county or some county east of these and the third in the southern half of the state . . . $6,000. The supervision of the experiments on peat lands is to be under the direct charge of experiment schools or stations of the Department of Agriculture situated nearest the three tracts that are secured for this purpose.

The ambiguous wording of this section of the appropriation bill clearly did not express the intent of the legislature, money not being needed for the leasing of the land, as this could be secured at a merely nominal expense, but for the carrying on of experiments upon such land. The appropriation item was unquestionably based upon a bill (O'Neill, S. F. No. 107, Pratt, H. F. No. 203) which itself failed to pass. In this the purposes were clearly specified and, acting upon an interpretation by the state attorney general, the money has been so employed by the university. It was as follows:

A Bill of an Act:

To provide for field experiments on peat lands in different parts of the state of Minnesota.

Be it enacted by the Legislature of the State of Minnesota:

Section 1. The Agricultural Experiment Station is directed to lease or otherwise secure at nominal cost for experimental purposes three tracts of land having a peat soil, one situated in either Beltrami county or some county west or if, another in either Koochiching, Itasca or Aitkin county or in some county east of these and the third in the southern half of the state.

Section 2. The size of each of the three tracts shall be not less than ten acres nor more than forty acres. Each tract shall be selected only after previous investigation and analysis of samples shall have shown that the peat on it is similar in character to that of the most extensive peat lands of the part of the state in which it is situated, and that on the whole or larger part of it the depth of the peat is not less than three feet.

Section 3. The experiment station shall conduct on each of the three tracts experiments planned to discover and demonstrate what crops, what varieties of such crops and what methods of drainage, cultivation, management, treatment and fertilization are best suited to each.

Section 4. To carry out the provisions of the above sections there is hereby appropriated from any moneys in the State Treasury, not otherwise appropriated, the sum of $10,000 for the fiscal year ending July 31, 1918 and $10,000 for the fiscal year ending July 31, 1919.

The locations of the three tracts finally selected are shown in Fig. 1. Through field and laboratory work in the preceding three years the character of the most extensive types of peat land in Northwestern Minnesota had already been determined. These peats had been found to be fibrous

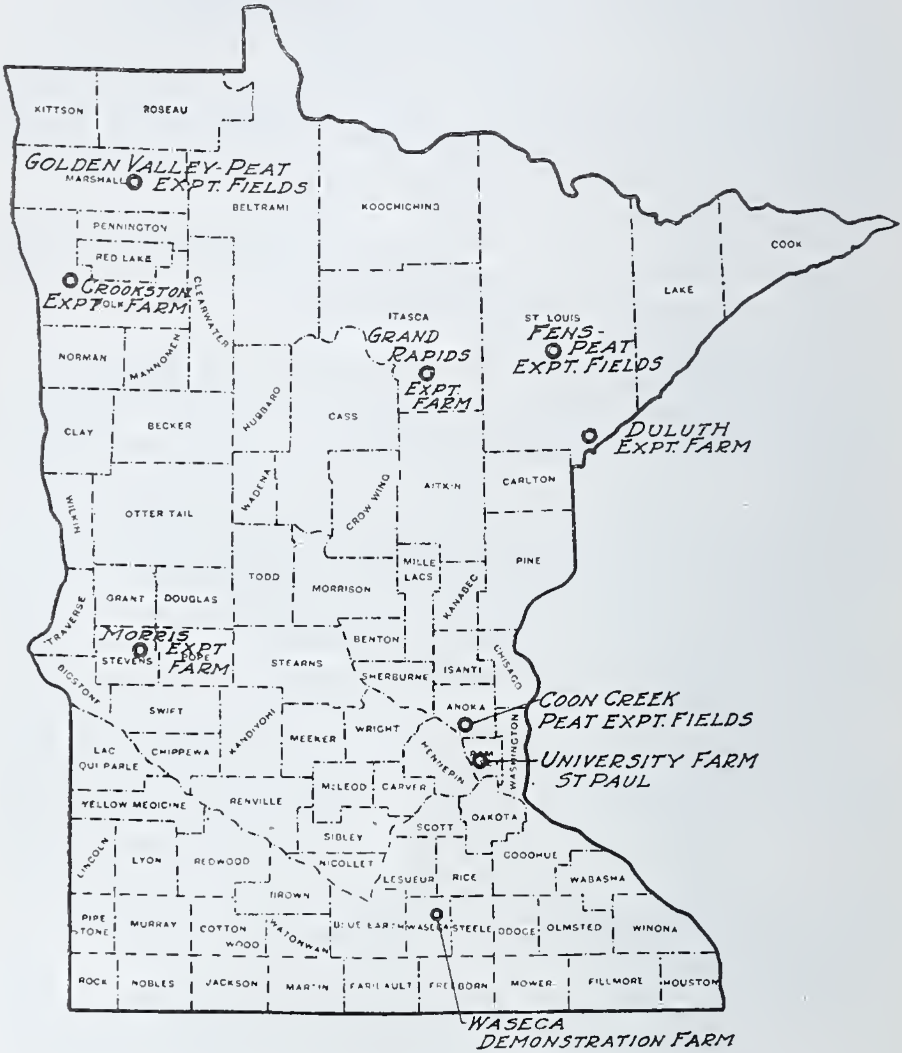

Fig. 1. Map of Minnesota, showing location of the Peat Experimental Fields provided for by Minnesota Legislature of 1917 as well as the various experiment substations.

and poorly decomposed; they are characterized by an abundance of lime, only a few lime-deficient bogs having been encountered. Most of the peat land which the farmers of that part of the state had tried to bring under cultivation had

been naturally covered by sedges and grasses; on most of it the peat layer is shallow, only from 10 to 30 inches in thickness, below which is clay loam, loamy sand or sand.

Drainage of these peat lands is provided by large open ditches, most of them many miles in length. As in most cases the ditches serve as the outlet for the water from still larger low, level tracts of mineral soil, any attempt to control, by means of gates or dams, the water level in the peat would result in water-logging the mineral soil served by the same ditches.

Location Of Experimental Fields.

The uncertainty resulting from the ambiguity in the wording of the appropriation delayed the search for a suitable location until late in September. What was most urgently needed was a temporary site for some experiments to be carried out in the crop season of 1918. For this work there was sought one field with peat soil, a part of which had never been burned, manured or fertilized, and a second field a part of which had just been burned. A location meeting these requirements exceptionally well was found on a farm a few hundred yards southeast of Golden Valley post office in Marshall County. While it might be thought that a site 14 miles from the nearest railroad station (Holt, on the G. N. R.) would be too inaccessible for visitors, the large number of farmers owning peat land who visited the experimental plots during the first season gave evidence that it was not too remote for the purpose intended.

For longer time experiments the University has secured the lease of a tract of virgin peat soil in the same neighborhood (D in Fig. 2), but still better situated, (Fig. 3 and 4) as well as a four year extension of the lease of the peat land under experiment in 1918. An appropriation made by the legislature of 1919 will allow the work to be continued through a second biennium.

The land was filed upon as a homestead in 1911 by the late Mr. T. G. Dahl, and now belongs to his widow, to whom with her sons and their families is due much of the success of the first year's work. At that time it was in a wild and undrained condition. A very wide and deep ditch, now passing on the north side, had been started the year before, but was not dug past the farm until 1912. A forest-covered island of mineral soil extended across the farm from west to east (Fig. 2), while both to the north and to the south the surface was formed by a grass and sedge covered peat layer,

varying in thickness from a few inches to more than three feet. The peat layer overlies a calcareous boulder clay, and between the two is a layer of black muck. The island, the main portion of which lies several feet higher than the peat land, consists of boulder clay with here and there a bed of sand or gravel, the surface soil being a black loam.

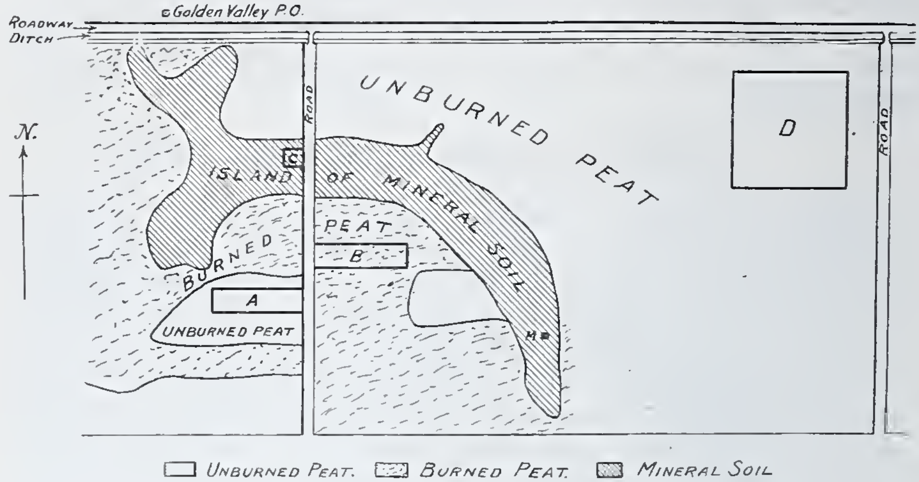

Fig. 2. Diagram showing relative locations of experimental fields at Golden Valley.

Fig. 3. Virgin peat land, July, 1918. This field was leased for the main experiments in 1919. Tree-covered islands of mineral soil appear in the distance.

Fig. 4. Preparing the seed-bed on a part of the same field as that shown above.

CROP HISTORY OF THE FIELDS.

The fields of which A and B (Fig. 2) form parts, were pastured in 1911, 1912 and 1913, in the autumn of the last year being broken 8 or 9 inches deep. The next season they were sown to flax, but the yield was low, only about 3 bushels per acre. In 1915 they were seeded with oats, the crop proving a complete failure. The following season the west field, of which A forms a part, was sown to oats once more and the other to barley, but both crops were failures. In October of that year part of the east field was burned over lightly and on this part a satisfactory crop of oats was secured in 1917. The other field, on which there had been no burning, was again sown to oats and seeded with timothy and clover, the oats again proving a failure, although a good stand of timothy and a rather thin stand of clover were secured.

After harvest in 1917 fires started in the peat in both fields, whether through accident or not, I do not know, but they were allowed to continue without any attempt to extinguish them until the middle of October, when the experimental tracts were arranged for. After the land shown as fields A and B, had been selected for the experimental work the burning of the latter was completed but the fire was kept 3 rods or more from the north side of the former. If any peat ashes had been blown upon field A from the burned land on the north they would have fallen most heavily upon the north side, the portion used for the unfertilized or check plots. Timely rains, however, had prevented any such blowing. Such a deposit of ash would have rendered the land quite useless for the intended experiment.

The burning in 1917 was deep, varying from 9 to 18 inches, with an average of about 12. (Figures 5 and 6.) Where the peat was shallowest it had in many cases been completely burned off, as on the east end of field B, such portions being indicated in Figure 8.

Thus field A represented unburned, unmanured, and unfertilized peat, and field B heavily burned peat.

No special provision was required for drainage, the large ditches alone sufficing. The season was far drier than the average while 1917 was the driest experienced in that part of Minnesota since records of the weather have been kept.

Character of the Peat Land.

The natural productivity of the peat land of the district is very low, as is well illustrated by the succession of crop failures on the fields described above. Flax has proven much the

most satisfactory crop. Stands of clover and timothy have been secured without difficulty, but unless manured, the plants have made little growth.

Burning, accidentally introduced into the district a few years before, had been practiced with satisfactory results

Fig. 5. A patch of partly burned peat, on July 23, 1918, which had been left untouched since burned in the preceding October. The burned portions are free of weeds altho none had been removed, the seeds having been destroyed by the fire. The crop seen in the background is spring rye on similarly burned peat.

Fig. 6. A block of plots on Field D, shortly after burning in August, 1918, ready for the disc or plow. The scattered unburned furrow slices of peat will not interfere with tillage.

but on only a small scale until the exceptionally dry summer of 1917, when several hundred acres were burned over, this being distributed over more than thirty farms. In 1918 heavy crops of grain were secured on most of this burned peat. The earliest burnings had occurred on fields where the peat was shallow and on these, where there is now little or no evidence of peat soil, no decline in productivity has been observed.

While the land was originally too wet for cultivation and much of the time too wet even for pasturage the large ditches constructed within the last few years have so lowered the water-table that in many cases, as on the experimental fields, it is now far below the bottom of the peat layer and the peat too dry for the production of wild hay.

The depth of the peat is somewhat less than when first drained, due both to the settling and to the compacting caused by pasturing animals.

A brown, tough, fibrous peat forms the surface few inches and a better disintegrated mass, quite similar in chemical composition, however, forms the lower levels. The analysis in Table 1, show that it is a true peat. The high content of lime indicated that applications of lime would be more likely to prove deleterious than beneficial to crops.

The ordinary soils surrounding and interrupting the peat lands are black loams or clay loams of high fertility. Differences in the productivity shown from place to place on these appear due to differences in the texture of the subsoil and hence to differences in the moisture supply, rather than to those of chemical composition.

TABLE 1.—Composition and Properties of Unburned Peat Soil on Golden Valley Experimental Fields.

A. Chemical composition of surface 8 inches from Field A.

Organic matter	87.7	per cent
Ash	12.3	per cent
Nitrogen	2.68	per cent
Lime (CaO)	2.59	per cent
Phosphoric acid (P_2O_5)	.25	per cent
Potash (K_2O)	.07	per cent

B. Weight per cubic foot from successive levels.

Depth	Old Field A	New Field D Site I	Site II	Site III
Inches	Pounds	Pounds	Pounds	Pounds
1 to 6	8.9	7.9	7.6	8.5
7 to 12	10.6	9.8	7.9	9.7
12 to 18	14.5	9.9	11.4	11.6
19 to 24	12.3	12.6	10.6	13.5

ARRANGEMENT OF EXPERIMENTAL PLOTS

Both fields of peat soil were divided, as shown in Figures 7 and 8, into six series, I to VI, separated by paths 2 feet wide, and each series into 2 blocks, separated by a roadway one rod wide. Each of these 26 blocks was subdivided

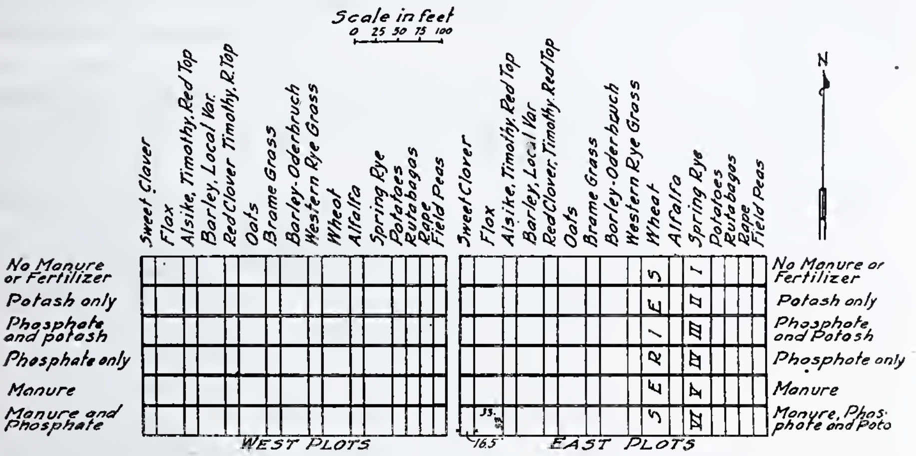

Fig. 7. Diagram showing arrangement of crops and fertilization on the unburned peat.

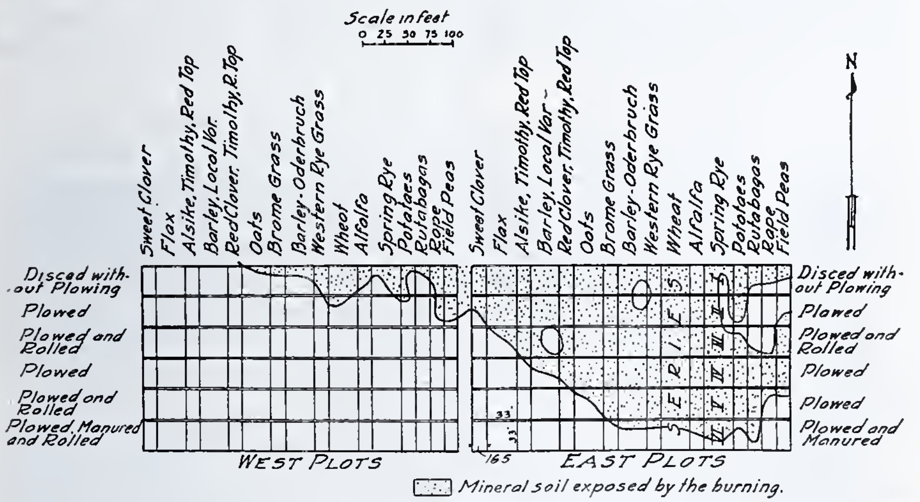

Fig. 8. Diagram showing arrangement of crops and tillage on the burned peat. The only fertilizer applied was manure, on Series VI.

into 16 plots, one for each of 16 different crops, thus making 384 plots in all. The plots were of two sizes, the larger, of one-fortieth acre, being used for all the grains except peas, and the smaller, of one-eightieth acre, for the other crops.

No paths were left between the plots but in seeding about half a foot at the edge of each plot was left unplanted. The yields have been computed the same as though the plot had been seeded right up to the line.

The paths separating the series were planted along with the plots and the crops allowed to grow on them until hoed out in the latter part of July to make the plot boundaries more evident to visitors, as well as to facilitate the later harvesting.

Roadways one rod wide surrounded each field, and these as well as those separating the blocks were kept free of weeds by discing and harrowing.

Every treatment with each crop on both fields was represented by two plots, except in the case of Series VI on both peat fields. With two tillage treatments on the burned peat, viz., plowing with rolling and plowing without rolling, each crop was represented by 3 and 5 plots, respectively.

Preparation of the Soil.

(a) **Unburned Peat.** Peat soils thaw out so slowly in spring that unless the seed-bed is prepared in the autumn seeding operations may be much delayed. The field had been plowed in the latter part of October, 1917, as soon as the lease was arranged, but the unusually early advent of winter prevented the intended preparation of the seed-bed before the ground froze. By April 20, 1918, the furrow slices were only partly thawed out and the peat below the plow line was still frozen solid. This rendered it impossible to prepare a good seed-bed and sow the small grains at that time, but the land was disced and harrowed repeatedly, the manure and fertilizers applied and the whole disced and harrowed again. In May the whole field was double disced, harrowed and rolled twice before seeding. In order to avoid dragging fertilizers from one series to another, all tillage operations were performed only east and west after the application of the manure, phosphate and potash.

The main problem to be solved was not one of cultivation, but of fertilization, and hence it was first of all necessary to prepare a good seed-bed, but the great amount of labor devoted to the preparation of this would not have been necessary if we could have left the work until the frost was out and the rains had put the soil in the most favorable moisture condition.

(b) **Burned Peat.** Series 1 (Fig.8) was not plowed, but was double disced in October, again in April, and lastly

in May, after which it was harrowed preparatory to seeding on May 16 and 17. The five other series of this field were first double disced, then plowed about 6 inches deep in October and again double disced on April 20. After this the cultivation varied from block to block. The whole of Series II and IV and the east blocks of Series V and VI were double disced and harrowed before seeding, while the other blocks received in addition several rollings with a heavy concrete roller (Fig. 9). The west blocks of Series III, V, and VI were rolled three times on April 20 and twice in May, while the east block of Series III received only the double rolling in May. In April the very wet condition of the soil on the east end of all the series, where the peat had been entirely burned off, placed the rolling of these out of the question except on Series III.

No commercial fertilizer was applied to any of the burned peat, but on Series VI stable manure was applied at the rate of 12 tons per acre just after the rolling in April. In the subsequent discing and harrowing the operations were performed only in an east and west direction so as to avoid dragging any of the manure from Series VI onto V. The differences in cultivation and treatment of the various series and blocks are indicated in Figure 8.

In October, 1917, when this experimental field was staked out on the burned land it had been the intention to give five of the series, viz: II to VI, the same cultivation, rolling them all, and, while leaving II unfertilized, to apply to the other

Fig. 9. Concrete roller for peat soils. It is very heavy, weighing over 3000 pounds, altho only 42 inches wide. Ordinary rollers are too light for satisfactory work on peat soils.

four the same fertilizer treatments used on Series II to V of the unburned peat (Fig. 7). However, as vegetation experiments carried out during the following winter had indicated that neither potash nor phosphate would show any beneficial effects upon the first crop following the burning, applications of these fertilizers were omitted. Having the land laid out and prepared for experimental work the plans were altered so as to introduce the experiment in rolling.

Fertilizer Treatments.

On the unburned peat we used both potash and phosphate singly as well as the two together, and also manure alone, manure reinforced by phosphate only, and reinforced by both phosphate and potash, as shown in Figure 6 and Table 2. As mentioned above, manure was applied to Series VI on the burned peat (Fig. 8.)

The discing and harrowing subsequent to the application of the fertilizers and manure was sufficient to mix them well with the soil, independent of the extent to which they would have been carried down by rains.

As phosphate fertilizer we employed 400 pounds per acre of acid phosphate carrying 15 per cent of phosphate. The potash used was applied in the form of Nebraska Potash Salts, 1000 pounds per acre, carrying 28 per cent of potash, an amount equivalent to that contained in about 600 pounds of the more commonly used forms, the sulphate and muriate of potash.

TABLE 2.—Fertilizations Employed, Showing Amount of Plant Food Constituents Added to Each Series, in Pounds per Acre.

Series	Block	Application, per acre	Phosphate (P_2O_5) Pounds	Potash (K_2O) Pounds	Nitrogen Pounds
		Unburned Peat.			
I	Both	None	0	0	0
II	Both	1,000 pounds potash salts...	0	280	0
III	Both	1,000 pounds potash salts and 400 pounds acid phosphate	60	280	0
IV	Both	400 pounds acid phosphate..	60	0	0
V	Both	12 tons stable manure......	60	120	120
VI	West	12 tons manure, 400 pounds acid phosphate	120	120	120
VI	East	12 tons manure, 400 pounds acid phosphate and 1,000 pounds potash salts......	120	400	120
		Burned Peat.			
VI	Both	12 tons manure	60	120	120

The manure was fresh from a horsestable in which wild hay had been used as litter, 12 tons per acre being employed. The composition of the manure reported in Table 2 is simply the average for ordinary farmyard manure, given for convenience of comparison. From this it will be seen that the 12 tons of manure may be assumed to have carried as much phosphate as the 400 pounds of acid phosphate.

Weather of the Crop Season.

The weather of the crop season compared with the normal may be seen from Table 3. The data reported from January to May are those for Thief River Falls, the nearest weather bureau station, 20 miles to the southwest. The meteorological instruments for Golden Valley were not available until the end of May.

The observations at Golden Valley, begun on June 1, have been made by Mrs. Carl Dahl, the instruments for convenience in reading being placed near her residence which is on a tract of mineral soil about a third of a mile east of Field B, (M in Fig. 2). It would have been desirable to have had daily observations of a minimum thermometer placed on Field A, but this was not feasible. However, a careful watch was kept for signs of injury from frost on the peat. No distinct injury to any of the crops due to frost was observed on the peat, and it appears that the last killing frost in the spring and the first in the autumn occurred on both the mineral soil and the peat at the same time, the dates for which were

TABLE 3.—Precipitation and Temperature at Golden Valley in 1917 and 1918 Compared with the Normal.

	—Precipitation, in Inches—			—Mean Temperature—		
	Normal(a)	1917(b)	1918	Normal(c)	1917(b)	1918
January	.55	.44	.33	—2	—5	—4
February	.56	.86	.21	1	—5	5
March	.98	.13	.12	16	21	32
April	1.84	1.26	2.49	28	36	40
May	2.85	.28	3.91	52	50	50
June	3.83	2.06	1.50	62	57	59
July	3.34	1.44	2.90	66	69	63
August	3.12	.59	2.51	64	64	63
September	2.32	1.20	.95	53	55	47
October	1.53	.84	2.37	41	31	45
November	.72	.15	.89	23	33	30
December	.56	.42	.59	7	—2	—
Year	22.22	9.67	18.77	35	34	—

(a) Average precipitation for Red River Valley.
(b) Observations at Thief River Falls.
(c) Average for St. Vincent-Pembina for 33 years.

May 13 and September 17. The average dates are about May 27 and September 12, thus giving 1918 a growing season at least two weeks longer than the average. Such a freedom of the peat lands in this district from summer frosts should be considered an unusual occurrence.

The previous season had been one of the driest recorded since observations were begun in northwestern Minnesota, and the winter snowfall was light. March was unusually warm and at the end of that month the seeding of wheat was begun on mineral soil in nearby fields. April also was warmer than normal and the precipitation very favorable for seeding. The weather conditions in May were similar to the average, while the three summer months were nearly normal in temperature, but drier than the average.

The weather of the crop season was far more favorable for grain crops than the data in the tables might at first suggest. The dry, very warm early portion of the spring permitted an unusually early start with seeding and the weather continued almost ideal for the purpose until this was completed. The rainfall in amount was barely sufficient to permit of very heavy yields of small grains, but its distribution was unusually favorable, and, as already mentioned, the last killing frost of spring was earlier and the first frost of autumn later than the average.

On the whole the season was one of the most favorable for small grains ever experienced in the northwestern part of Minnesota. It is probable that this statement applies to the peats even more than to the mineral soils.

In the case of hay crops, the low precipitation prevented good yield being obtained, especially as 1917 had been a remarkably dry year. A much wetter summer would have been more favorable for grasses and clovers of all kinds on both mineral and peat soils.

Planting.

All the crops except potatoes and rutabagas were seeded by Prof. R. O. Westley of the Crookston substation on both fields May 15 and 16, the same rates being used on all and each crop being in turn planted on both fields before starting on the next crop. The potatoes and rutabagas were planted by Mr. T. M. McCall of the same substation on May 29. The seed germinated well and a good stand of all crops was secured.

Trouble With Weeds.

In recent years the sow thistle has become very troublesome in the northwestern corner of the state and probably

in no district is it now worse than in that around the experimental fields. At the first of August the yellow blossoms of this weed give their color to the landscape to such a degree as to make the name Golden Valley, exceptionally appropriate.

About the middle of June this thistle had appeared in such numbers on all the plots on the unburned peat and on the mineral soil that if the weeds had not been pulled it is doubtful whether there would have been much grain or grass in these fields to harvest. On the unburned peat they were especially bad while on the burned peat only an occasional thistle or weed of any kind appeared, the seeds having been destroyed when the surface was burned the preceding autumn, and the very few that did appear might have been left without appreciably lowering the crop yields. About the middle of June the thistles threatened to ruin all the experiments on the unburned peat, but during the latter half of that month and the early part of the next all the available boys, girls and women of the thinly settled district were employed in pulling the weeds. Before being removed the thistles doubtless did a certain amount of damage to the grains and grasses, and the pulling, with the accompanying unavoidable tramping, caused some further injury. In the potatoes and rutabagas they were kept down by repeated hoeings, but still they probably lowered the yields. Many thistles appeared in the grains and grasses after July, but these were not pulled. They did not make sufficient growth before harvest to contribute appreciably to the weights of straw and hay removed from the plots.

As throughout the whole summer but few weeds appeared on the plots on the burned peat and these were pulled, the crops on that field were given a decided advantage over those on the unburned peat.

Appearance of Crops During Growth.

From the middle of June onward the benefit of both the phosphate and the manure, as well as burning, was very evident. The potash treated plots were at all times practically indistinguishable from the adjacent untreated ones, while those with the four other treatments on the unburned peat were all much alike and all markedly superior to the preceding two. To this generalization there were two exceptions, viz: flax and wheat. The former made a fairly good growth on the untreated peat and except early in the summer showed little or no benefit from the phosphate, and less from the manure than did any of the other crops. Early in the season the wheat showed as much benefit from the

phosphate as did the other grains, but about the middle of July a disease appeared on all the plots receiving either phosphate only or phosphate and potash and the crop steadily declined until harvested.

While on the burned peat the crops in general were equal to or better than the best of those on the unburned peat, the flax on the former was a complete failure. The seed germinated well but the plants gradually died out until by the latter part of August almost all had disappeared.

The growth of straw of the other small grains became very rank on the burned plots and the oats and barley lodged badly before the end of July, the condition becoming much worse during August. By the time harvest had arrived all the plots of barley and oats were down so badly that they could be cut only with a mower. The spring rye suffered least from lodging, it standing up sufficiently to permit the use of a binder.

On the unburned peat there was but little lodging.

Harvesting.*

The various crops were harvested as fast as they matured. (Table 4.) With barley, oats, and rye the crops on the untreated and on the potash-treated unburned peat matured more slowly, and when ripe on all the other plots were still somewhat green on these. In such cases all the plots in a field were cut on the same day, the difficulty of securing labor making it necessary to reduce the work as much as allowable.

The clovers and grasses on many of the plots had made such a growth that at the end of August all were cut for hay. In some cases, in determining the yields, the hay was allowed to lie in the swath until cured, then raked up and weighed. In the latter case weighed samples of the green material were taken and placed in a well aired barn loft to dry, after which they were weighed again and from the data the yields of cured hay computed. In the case of each hay crop all the plots were cut on the same day and the whole row of six plots in a block in Fields A and B treated alike, they being either allowed to cure in the swath or weighed green and sampled.

A summary of the yields of the various crops are reported in Table 5, except those for Series VI in which the

*The harvesting and threshing were carried out by Mr. Jouette C. Russell, Mr. Paul R. McMiller, and Mr. George H. Nesom of this experiment station.

plots were not in duplicate, the latter being given in Table 6. The data on the individual plots will be given in detail in the first report of the Golden Valley Peat Experimental Field, which is soon to be published as a bulletin of the Minnesota Experiment Station. The weight per measured bushel of the grains is reported in Table 7.

Table 4. Crops under experiment with dates of planting and harvest.

Crop	Variety	Date of Planting	Date of Harvest
Wheat	Marquis	May 15	Sept. 2
Spring rye	....	May 15	Sept. 2
Barley	Oderbrucher	May 15	Aug. 24(a)Aug. 26
Barley	Local seed	May 15	Aug. 26
Oats	Minnesota No. 295	May 15	Aug. 27(a)Sept. 3
Flax	Minnesota No. 25	May 15	Sept. 25
Field peas	Canadian White	May 15	Sept. 23
Potatoes	Early Ohio	May 29	Sept. 21
Rutabagas	American Purple Top	May 29	Sept. 22
Rape	....	May 16	Aug. 30
Alfalfa	....	May 16	Aug. 27
Sweet clover	White Biennial	May 16	Aug. 27
Western rye grass	....	May 16	Aug. 26
Brome grass	....	May 16	Aug. 26
Grass mixture	Red clover, timothy and redtop	May 16	Aug. 29
Grass mixture	Alsike, timothy and redtop	May 16	Aug. 29

(a) On the burned peat.

Table 5. Yields per acre of various crops on the Golden Valley peat experimental fields, from treatments represented by two or more plots each in 1918.

	Unburned Peat					Burned Peat			
	No manure or fertilizer	Potash	Phosphate	Phosphate and Potash	Manure	Not Plowed	Plowed	Plowed and rolled	Plowed and manured
(a) Small Grains.									
Wheat—									
Grain, bush.	6.6	6.6	4.8	4.1	13.9	12.5	12.9	12.4	16.6
Straw, pounds	1189	1186	1820	1571	3172	4980	4864	5269	5341
Spring rye—									
Grain, bush.	14.6	14.1	39.6	38.5	36.8	45.6	46.0	59.7	37.3
Straw, pounds	1589	1573	3706	4307	3922	4114	4179	5321	3531
Oats—									
Grain, bush.	32.8	35.0	81.3	72.1	71.7	53.3	70.0	66.4	97.6
Straw, pounds	1204	1397	3666	3933	3241	4072	3902	5031	3928
Barley, Oderbrucher—									
Grain, bush.	7.4	11.2	24.6	30.0	25.3	42.6	46.6	42.4	50.3
Straw, pounds	898	1299	2402	3006	2754	4362	4864	4656	4686
Barley, local var.									
Grain, bush.	14.4	14.1	26.3	31.7	32.7	47.2	58.3	49.9	61.8
Straw, pounds	783	847	1772	1746	1736	2800	3896	4036	3426
Flax—									
Grain, bush.	8.2	8.7	5.9	7.7	10.7	Complete Failure			
Straw, pounds	718	712	1000	1204	1185	Complete Failure			
Field Peas—									
Grain, bush.	10.8	10.2	18.2	15.7	24.2	19.3	24.1	22.0	18.6
Straw, pounds	1544	1624	3499	3480	3370	2359	3118	3031	2882
(b) Root Crops and Rape.									
Potatoes—									
Bushels	59	63	90	101	102	157	176	173	199
Rutabagas—									
Bushels	45	35	144	148	241	394	371	388	295
Rape, green—									
Tons	1.7	1.8	12.2	12.7	11.4	20.6	17.6	16.0	14.4
(c) Grasses and Clovers as Tons of Cured Hay.									
Alfalfa	.04	.04	.50	.20	.66	.56	.68	1.08	.96
Sweet clover	.04	.36	2.58	3.64	2.64	2.94	3.42	3.96	3.84
Brome grass	.04	.06	.62	.64	.44	.92	1.44	1.62	1.18
Western rye grass	.12	.16	1.18	.72	.68	1.12	1.22	2.09	1.04
Red clover, timothy and redtop	.04	.04	.84	.60	.66	1.20	1.39	1.48	1.60
Alsike, timothy and redtop	.04	.04	.80	.44	.68	1.36	1.53	1.82	1.00

Table 6. Yields per acre of the same crops in 1918 on the same fields as in Table 5 from treatments represented by only one plot.

	Unburned Peat		Burned Peat
	Manure and phosphate.	Manure, potash and phosphate.	Plowed, manured and rolled
(a) Small Grains.			
Wheat—			
Grain, bush.	11.2	16.9	10.9
Straw, pounds	3159	3044	5479
Spring rye—			
Grain, bush.	40.7	49.6	54.7
Straw, pounds	3493	6643	4769
Oats—			
Grain, bush.	77.2	90.4	89.4
Straw, pounds	4163	2795	6846
Barley, Oderbrucher—			
Grain, bush.	27.8	18.8	39.0
Straw, pounds	2689	1988	4195
Barley, local var.—			
Grain, bush.	33.3	24.3	52.2
Straw, pounds	1922	1248	3845
Flax—			
Grain, bush.	8.6	14.7	Complete Failure
Straw, pounds	1267	1368	Complete Failure
Field peas—			
Grain, bush.	24.9	20.1	19.5
Straw, pounds	2428	3160	2994
(b) Root Crops and Rape.			
Potatoes, bush.	120	92	188
Rutabagas, bush.	205	218	284
Rape, green, tons	4.8	15.4	15.5
(c) Grasses and Clovers as Tons of Cured Hay:			
Alfalfa	.56	.64	.28
Sweet clover	2.24	2.28	2.97
Brome grass	.76	.72	1.36
Western rye grass	.84	.36	1.96
Red clover, timothy and redtop	.76	.48	1.08
Alsike, timothy and redtop	1.00	.80	.96

Table 7. Weight per measured bushel of grain on unburned and burned peat.

	Unburned Peat					Burned Peat
Crop	No manure or fertilizer Pounds	Phosphate only Pounds	Potash only Pounds	Phosphate and Potash Pounds	Manure Pounds	Pounds
Wheat	50	53	50	52	50	46
Spring rye	55	57	55	57	57	57
Oats	36	39	37	40	33	40
Barley, Oderbrucher	38	42	38	40	43	42
Barley, local var.	43	47	44	47	48	46
Flax	57	57	57	57	57	..
Field peas	58	60	58	60	61	61

CROP NOTES.

Spring Rye. This proved the most satisfactory of the small grains on both the peat fields, giving heavy yields of grain of good quality and remaining sufficiently erect even on the burned peat to present no difficulty in harvesting with a binder. As the influence of the different forms of fertilization and tillage upon the rye was typical of that with nearly all the other crops its growth will be described in more detail than that of any other.

The fine condition of the seed-bed and the frequent rains during the first three weeks following the seeding produced a very uniform stand of plants which made rapid growth on the burned peat and the mineral soil as well as with four of the six treatments on the unburned peat. By the tenth of June the differences on the peat had become very distinct, the rye on all of the plots on the unburned peat that had received either phosphate, manure or both, being taller and more stooled, while by the twentieth of the month twice as much growth appeared to have been made on these as on the plots which had remained unfertilized or had received potash only. At this time the crops appeared distinctly better on the plots receiving phosphate only than on those receiving manure only.

At the same time the crop on the burned peat was good on all the plots but much more growth had been made on those which had been rolled, they being distinctly better than even the best on the unburned peat. At no time on the burned peat did the manured plots appear distinctly better than the unmanured.

As the season advanced the marked differences on the unburned peat, in favor of the phosphate and the manure, continued distinct. The superiority of the phosphate-treated plots over those which had been manured, observed early in the summer, gradually lessened until it disappeared about the end of July. Likewise, the beneficial effect of the rolling on the burned peat became less and less evident. The effects of both potash and phosphate are shown by Figures 10 and 11.

During August the crops on the plots on unburned peat that had received no fertilizer, or potash only, improved steadily and at harvest time were much better than they had promised early in the month. The potash treatment at no time showed either a beneficial or a harmful effect. On both these series the crop matured later than on all others. The grain on all the plots was harvested as soon as it ripened on the latter.

From Table 5, it will be seen that both phosphate and manure gave very marked increases. Less than 15 bushels

No Fertilizer. Potash.

Fig. 10. Effect of potash on spring rye, July 23. It causes no improvement.

No Fertilizer. Acid Phosphate.

Fig. 11. Effect of phosphate on spring rye, Aug. 26. The unfertilized rye yielded 14.6 bushels per acre and that with phosphate, 39.6 bushels.

per acre was obtained on the untreated peat, while where either phosphate or manure was used the yield exceeded 36

bushels. Even a higher yield was obtained on the burned land, it averaging 59 bushels on the plots which had been both plowed and rolled.

Potash showed no beneficial effect, either alone or when used along with phosphate.

The grain from the peat which had received phosphate or manure or had been burned was of fine quality and weighed 57 pounds per measured bushel (Table 7), compared with 55 from the other plots.

Wheat. For the reasons stated above seeding had to be delayed until May 16, much too late a date to give this crop a fair trial. On the various plots on the peat the wheat was quite similar in appearance to that on the corresponding ones of rye, the phosphate, manure, burning and rolling all showing a similar benefit, while potash was without any. This similarity ceased about the middle of July when the wheat was attacked by disease on the unburned peat which had received either phosphate alone or both phosphate and potash. Later rust attacked all the wheat plots on Fields A and B, with the result that on all the yield was low and the quality poor, the weight per bushel varying from 46 to 53 pounds.

Oats. During its growth this crop showed the same response to the different forms of fertilization and tillage as did the rye, being far the best on the plots which had received phosphate or manure or had been burned (Fig. 12). On all the burned plots the grain began to lodge badly early in August and before it ripened was down to such an extent that it could not be harvested with a binder.

On the unburned peat, on which there was no lodging, the grain was cut as soon as the plots which had received manure or phosphate were ready, those which had received no treatment, or potash only, appearing somewhat green at the time. However, the quality of the grain from even these two treatments was very good, the weight per measured bushel being 36 to 37 pounds. The grain from all the plots which received phosphate or manure, or were burned, was still better, weighing from 38 to 40 pounds. The heaviest of all was that from the burned field, notwithstanding the lodging.

On the unburned peat the effects of the different treatments were similar to those with the rye, but on the burned peat the yields were much more variable because of the lodging. On three of the burned plots this was so bad that no attempt was made to gather the crop. On the unburned peat both the manure and the phosphate caused an increase of more than 100 per cent, or about 40 bushels per acre.

Barley. Two different lots of seed were used with this grain, the one Oderbrucher from the Crookston sub-station

and the other a local strain of an unidentified variety which was sown on plots intended for speltz, but for which the seed failed to arrive in time. The local variety yielded somewhat the better.

During the earlier part of the season the same differences were shown as with the rye and oats, but near the end of July the barley began to lodge on the burned plots and as with the oats, the lodging steadily grew worse, finally being so bad that the crop could not be cut with a binder.

With both varieties the effect of the different treatments upon the yield of grain was similar to that with the oats, the phosphate, manure and burning causing great increases, while the potash showed no effect (Fig. 13 and 14). The burning gave much the best yield of all. The grain was of only fair

No Fertilizer. Acid Phosphate.

Fig. 12. Effect of phosphate upon oats, Aug. 26. The unfertilized plots yielded 32.8 bushels, while those with phosphate gave 81.3 bushels per acre.

quality, being heaviest on the plots receiving either manure or phosphate. Like the oats and rye the barley on the unburned peat which had received neither phosphate nor manure appeared somewhat green when harvested.

Flax. This started well on all the plots but early in July it began to die out on all those on the burned peat, and by the end of the month only a thin stand of sickly plants remained (Fig. 15). On all of these it was a complete failure and at the end of August, the plants being nearly all dead, the plots were plowed.

On the unburned peat where the stand remained satisfactory, the phosphate showed a distinctly beneficial effect early in the season, but later this difference disappeared. The manured plots throughout the latter part of the season

Potash Alone. Potash with Phosphate.

Fig. 13. Effect of phosphate upon barley, which is in the foreground. Spring rye appears in the background and upon this may be seen the effect of two additional treatments. July 23.

Phosphate and Potash. Phosphate Only.

Fig. 14. Effect of potash upon barley. The same field as the above. The barley on the plot receiving phosphate only is similar to that on the one receiving potash in addition. The rye in the background shows the effect of various treatments. July 23.

appeared distinctly the best and gave the heaviest yields. On all the plots the crop ripened without injury from frost and the seed from all was alike in weight, 57 pounds per measured bushel.

Field Peas. In the early part of the summer these made a relatively better growth on the unfertilized, unburned peat than any other crop except flax. Also, during the early part of the summer it showed but little benefit from the burning. However, at harvest time the difference in favor of phosphate manure and burning was marked, the last giving the best yields.

Fig. 15. Crops on burned peat, showing failure of flax. Flax with a thin stand of sickly plants occupies the foreground, while beyond is to be seen a heavy crop of barley already beginning to lodge. Between the two is the alsike-timothy-redtop plot. July 23.

The explanation of the great difference in yield between the two plots receiving potash and phosphate is not known. The one in the east block yielded only 9.3 bushels compared with 22.1 from the west block, although it had appeared the most vigorous of all those on the unburned peat and the yield of straw was heavy. As this plot was beside a public roadway and there were a great many visitors it may be that many more pods were picked on this than on any of the others.

The weight per measured bushel was highest on the burned, manured, and phosphate-treated plots, but not so high on any of these as on the mineral soil.

Grasses and Clovers. The various plots of grasses and clovers seeded about the middle of May were intended for hay in 1919, but by the end of August part of them showed a very heavy growth and all were mown and the yields of hay determined.

The sweet clover and alfalfa plots were treated with soil from an old alfalfa field at the rate of 300 or 400 pounds per acre. The weather at and immediately following seeding was

very favorable for the germination of the seed and a good stand was secured on all the plots. Near the close of a dry period ending July 4 the plants on the unburned peat were suffering severely but they quickly recovered after the rains. On the burned peat the rolled plots were much superior to the others, especially throughout the early part of the summer.

No Fertilizer. Acid Phosphate.

Fig. 16. Effect of phosphate on clover timothy mixture Aug. 26. The stand is good on both plots but the plants on the unfertilized were so short that it gave only a tenth as much hay.

Acid Phosphate. Unburned and Unfertilized. Burned.

Fig. 17. Effect of phosphate and burning upon sweet clover. Aug. 26.

On no other crops were the beneficial effects of both phosphate and manure more distinct, the plots receiving these treatments yielding at least ten times as much as the unfertilized peat. Burning gave similar results. The differences

shown by the tables were considerably greater than would have been found if the plots had been pastured, for the reason that there was a good stand of plants on the unfertilized plots, but these were so short that only a small portion reached above the mower-knife (Fig. 16). However, any of the treatments that included either phosphate or manure would have furnished many times as much feed to pasturing animals as the unfertilized peat.

Much the heaviest yields of hay were given by the sweet clover and on this crop the effect of the various treatments was most marked (Fig. 17).

Potatoes. These showed the beneficial effect of both phosphate and manure on the unburned peat but both yield and grade were far superior on the burned to the best on the unburned.

Nine of the plots were harvested on August 29 and the others on September 21.

Rutabagas. The burned peat gave much the heaviest yields and the roots were of much better shape on the burned peat than on even the manured or phosphate-treated peat. The yield was three times as heavy on the last as on the unfertilized. The potash showed as little effect with this crop (Fig. 18) as with the others.

Phosphate and Potash. Potash Only.

Fig. 18. Rutabagas showing effect of phosphate. Spring rye in the background shows a similar effect upon height of plans. Aug. 26.

Rape. This crop was cut green, using a mower, and weighed at once. The markedly beneficial effects of phosphate, manure and burning are as conspicuous as with the hay crops.

EFFECT OF THE VARIOUS FERTILIZER TREATMENTS.

From the above tables and from Fig. 19, it will be seen that both phosphate and manure gave greatly increased yields with all the crops except flax and that the potash was without any distinct effect either when applied alone or along with the phosphate. With some crops the yields were higher on the plots which had received no potash, while on others the opposite was true. Such differences are to be attributed to unavoidable irregularities in the character of the soil, drainage, injury by weeds, etc., and not to the effect of the treatment. This is made evident by a comparison of the yields on the various pairs of plots receiving the same treatment and bearing the same crop.

In general, the manure alone caused somewhat higher yields than the acid phosphate alone, while the manure reinforced by either phosphate alone or by both potash and phosphate gave, on the whole, no better yields than the manure alone.

As mentioned above it may be assumed that the quantity of manure applied contained as much phosphate as the 400 pounds per acre of acid phosphate (Table 2) and in addition a large amount of potash and also of a third fertilizing constituent, nitrogen, the one in which our mineral soils are most apt to be deficient. The superiority of the manure-treatment over the phosphate-treatment is to be attributed either to this added nitrogen or to the increased decomposition of the peat due to the addition of large numbers of bacteria, or partly to each.

PROBABLE RESIDUAL EFFECT.

Only a part of the beneficial effect of the application of manure or of the acid phosphate where these cause crop increases is exhausted in the first season. With the phosphate the amount remaining in the soil within reach of plant roots and in an available form probably closely approaches the difference between the amount added and that removed in the form of crops. As the soil is abundantly supplied with lime the water-soluble acid phosphate is soon largely changed into an insoluble phosphate of calcium in which form it may be expected to remain available. The residual amount com-

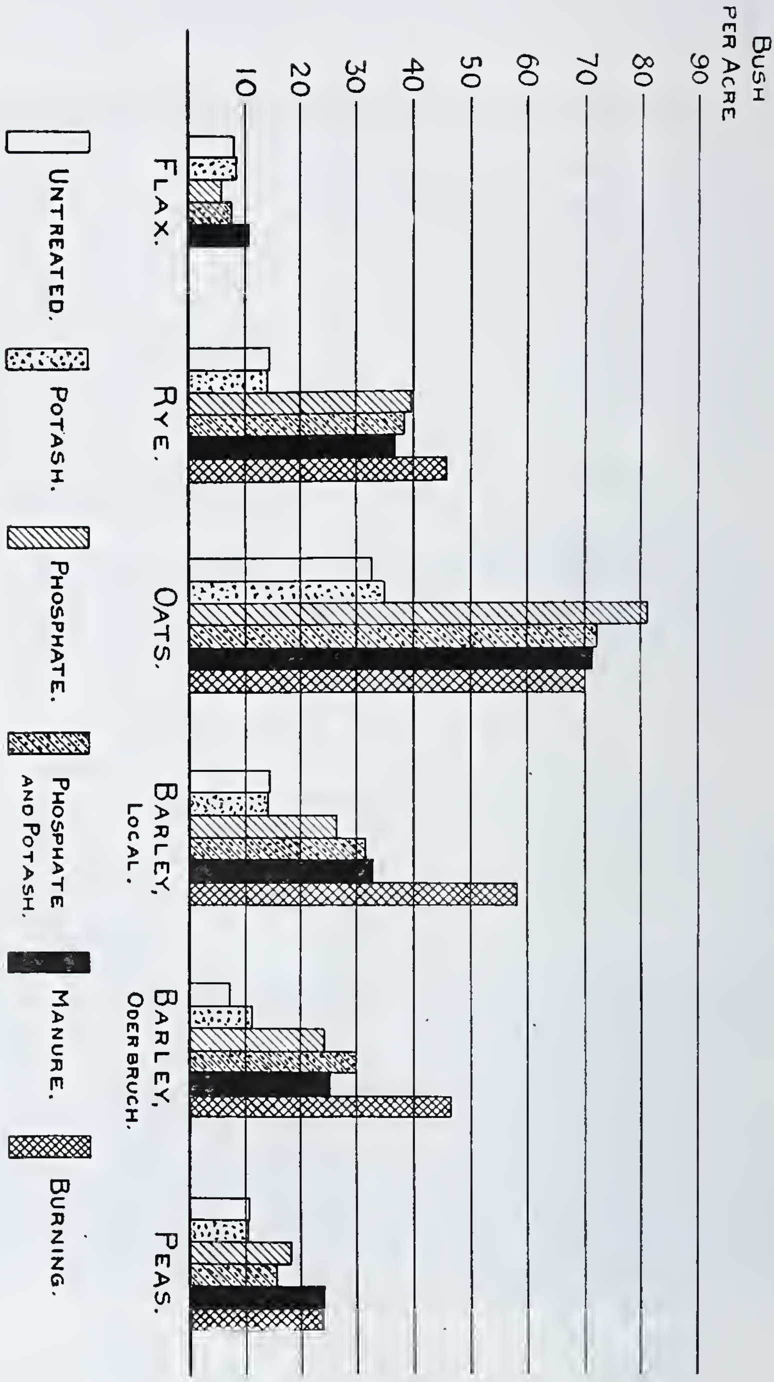

Fig. 19. Effect of different treatments upon the yield of small grains.

puted for the plots bearing the crops which gave the heaviest yields and drew most heavily upon the phosphate of the soil, assuming that these crops were of average chemical composition, lies between one-half and two-thirds of the phosphate added. This large amount may be expected to show a marked, but gradually decreasing, benefit upon the crops of succeeding years so long as the supply of potash in the peat remains sufficient for crop needs, but the heavier crops resulting from the phosphate applications will make a correspondingly heavier draft upon the potash supply.

In European experience it has been found that where the peat is deficient in phosphate it is most profitable to give a liberal dressing of a phosphate fertilizer in the first year, light applications during the next 2 or 3 years and in each of the following seasons to apply enough to supply a little more than the amount removed in the crop.

The potash was applied in a water soluble form and, as it, unlike the phosphate, is only in part held by the peat soil against downward movement in the water, part of it, even within the first year, may be carried through the peat layer and down into the upper portion of the underlying mineral substratum where it will be retained largely in a form available to plants. However, to secure it the plant roots would have to penetrate to this depth.

As the potash caused no distinct crop increases the most of that added may be assumed to still be retained, either entirely in the peat or partly in the underlying muck layer, and hence available for the crops of later years. The same would hold true for the potash contained in the manure applied.

As soon as the available potash originally contained in the peat approaches exhaustion we may expect to see great differences in yield between Series III and IV on the unburned peat. In view of the universal European experience with peat soils we must count on a potash deficiency appearing rather suddenly after the peat lands have been cropped for a few years without any potash fertilizer unless within that period the crop plants become able to root sufficiently deep to secure their potash supply from below the peat layer.

Hence the question as to how soon potash fertilizers will become essential on this type of peat cannot yet be answered.

EFFECT OF BURNING.

The very beneficial effect of burning is evident from the table of yields (see also Figures 20 and 21). The explanation is simple. The large amounts of phosphates held in the peat in a form that is unavailable to the plant roots is changed by

the burning into a readily available form and hence the result is similar to that of the addition of a phosphate fertilizer. The amount of phosphate thus liberated by burning off the surface 6 inch layer of peat would amount to about 300 pounds

Fig. 20. Plots on the burned peat, Aug. 26, with sweet clover in the foreground and farmstead on mineral soil in the distance.

Fig. 21. Another view on the same field as above, on July 23, showing spring rye at the left, potatoes in the center and rape to the right.

of phosphoric acid per acre, an amount equivalent to that contained in 2,000 pounds of acid phosphate or 60 tons of stable manure of average composition.

In addition to the phosphate the burning sets free a

great amount of lime together with a small amount of potash, but in the present case the addition of neither of these is to be considered beneficial.

Another result of burning is to make the nitrogen more readily available and hence the effect of the fire is to supply an abundance of available phosphate, a small amount of potash and an increased amount of available nitrogen.

The removal by fire of the coarse surface layer of peat such as occurs at Golden Valley permits the preparation of a finer and better seed-bed, and in addition, the lessening in the thickness of the peat layer, where originally shallow, may be assumed to facilitate the penetration of the plant roots to the underlying mineral soil, and thus increase the available supply both of plant nutrients and of moisture.

It appears that a much shallower burning than that which occurred on Field B would have furnished sufficient phosphate and yet have caused a lessened degree of lodging and so have improved the yield of both oats and barley.

The length of time that the burning will suffice to make such peat soils productive is doubtful, probably much depending upon the depth of the remaining peat layer. Where this has been wholly burnt off or made very shallow and a black loam or clay loam is thereby exposed it is probable that the burned peat will behave much like a mineral soil and under continuous cropping without manure or commercial fertilizers decline in productivity only very gradually.

The yields from the plots which had been simply disced after burning were, on the whole, somewhat lower than those which had been plowed.

The advantages of rolling unburned peat are so fully established that experiments to determine the effect appear almost superfluous. On the burned peat where the remaining peat layer is still too deep to be penetrated by the plow we should expect somewhat the same beneficial effect.

Throughout the early part of the season the crops on the rolled plots were in general much superior to those on the unrolled, this being especially evident with all the grasses and clovers, but as the season advanced the difference lessened until at harvest time only the hay crops were distinctly better on the rolled land. With the small grains there was a heavier yield of straw but in most cases a lighter yield of grain due to the ranker growth and increased lodging.

The manure showed no beneficial effect on either the unrolled or rolled land, evidence that the burned peat furnished all the available nitrogen that the crops could make use of.

GENERAL CONCLUSIONS.

The main conclusions to be drawn from the first season's experiments are very evident. The supply of lime and available nitrogen are abundant for the production of all crops suitable for this part of the state, and the potash supply is fully equal to the needs of the first year and perhaps even of the first few years.

The phosphate supply is so very deficient that satisfactory yields of no crop except flax were obtained without adding this constituent in the form of either acid phosphate or manure. When either of these was added good yields were obtained, as high as when the two were added at the same time.

A heavy burning of the peat gave very heavy yields of most crops, no matter whether all the peat or only part of it had been burned off.

Owners of peat land similar in character to that on the Golden Valley farm have three methods of procedure open to them, if the peat is too deep to be productive by the farming methods used on the ordinary soils, viz., the use of farm manure, acid phosphate or burning. The extent to which the first may be used depends upon the amount of stock the farmer is keeping, and the last upon the weather and the general drainage conditions as well, while the second can be employed to any desired extent and in any season.

How long the use of phosphate, unaccompanied by any form of potash fertilizer, will permit the satisfactory farming of these naturally unproductive peats is very uncertain, apparently depending upon the original depth of the peat, and upon the type of farming followed.

As most peat soils need potash fertilizers from the time that they are first brought under cultivation, and some need an application of lime as well, peat land owners of the district desiring to reclaim these lands are advised to limit their work in the first season to an experimental scale.

Burning the surface layer, which in some cases is desirable and which at times is very profitable, should be employed only after a careful consideration of the local conditions. Burning may ruin the drainage system, produce an alkali soil, leave a boulder field, or, in the case of shallow peats, leave too little organic matter. The crop results in the first season after burning are usually excellent, but the beneficial effect either disappears the first season or gradually and rapidly becomes less, unless the peat layer be shallow and

underlaid by a good mineral soil. Burning, when practised, should always be carried out with extreme precautions to prevent the escape of fire.

PEAT IN 1918.*

By C. C. Osbon.

Introduction.

The progress of the domestic peat industry since it attained commercial proportions in 1908 constitutes an interesting phase of the development of our mineral resources. Though extensively used as fuel in Europe and widely known in the United States as a potential source of heat and power, peat has been unable in most parts of this country to compete with coal, and consequently many peat operators have directed their attention to the uses of peat in agriculture, with the gratifying results recorded in this report. Peat fertilizer first entered the markets in commercial quantities in 1908 and stock-food peat in 1912, and though there is still some prejudice against the use of these products the agricultural branch of the peat industry has been successful and the quantity of fertilizer and stock-food peat annually produced is increasing. In 1918 peat fuel for the first time since 1914 entered the market in commercial quantity.

The notable increase in the output of peat in recent years, and especially in 1917 and 1918, is ascribed to the shortage and of high price of coal and nitrates, to the nation-wide demand for increased production of food, to a better understanding of the nature of peat, and to the application of bacteriology to the cultivation of crops. It is believed that these conditions, though in part created by the war, will in large measure continue to exist in this country, that the demand for peat products will correspondingly increase, and that peat will maintain and even better the position it has taken in 1918 in the industrial progress of the United States.

PEAT INDUSTRY.

General Conditions.

The greatest activity and expansion in the history of the domestic peat industry took place in 1918. The output of crude peat far exceeded the quantity produced in any preceding year, and nearly all branches of the industry shared in the increase. Large quantities of fertilizer and

*Reprint from U. S. Geological Survey.

stock food were manufactured from peat, but the most striking development of the year was the production of more peat fuel in New England than has been manufactured commercially in the entire United States in all preceding years. Almost equally striking were the large quantity of peat moss produced and the wide-spread interest manifested in our peat resources, which had heretofore been popularly regarded as of little value.

The total number of plants at which peat was commercially produced in 1918 was 25, an increase of 7 over the number operating in 1917. All the plants that operated in 1917 except four contributed to the output of peat in 1918, and 11 that were not represented in 1917 reported commercial production. Many new companies were organized in 1918, but did not complete their preliminary work in time to contribute to the year's output. Some stated that they could not obtain necessary machinery, but it seems that this situation has improved. As illustrated by Plate III, the plants known to be operating in 1918 were distributed as follows: California, 2; Connecticut, 1; Florida, 1; Georgia, 2; Illinois, 2; Indiana, 2; Maine, 1; Massachusetts, 3; New Hampshire, 1; New Jersey, 4; New York, 4; North Carolina, 1; Pennsylvania, 1. Peat moss was also gathered by hand in Washington, Oregon and Maine.

Nearly all producers reported that the demand for peat exceeded the supply, and it was stated by some that on account of meager facilities they were unable to fill the orders of their regular customers.

Many peat plants that operated in 1918 made improvements in order to increase production in 1919.

PRODUCTION.

Crude Peat.

The quantity of crude air-dried peat produced in the United States in 1918 was 151,521 short tons—54,158 tons, or nearly 56 per cent, more than the record output of 97,363 tons in 1917.

Nearly all producers of crude peat in this country use their entire output in the manufacture of peat products, and it was therefore impossible to determine accurately the value of the raw material. However, the average price received for all peat products in 1918 was $9.76 a ton, and the gross market value was $1,047,243, a gain of $2.47 in average price per ton and of $337,343, or approximately 48 per cent, in gross market value compared with 1917.

The accompanying tables and figure show that the output of crude air-dried peat has materially increased in recent years.

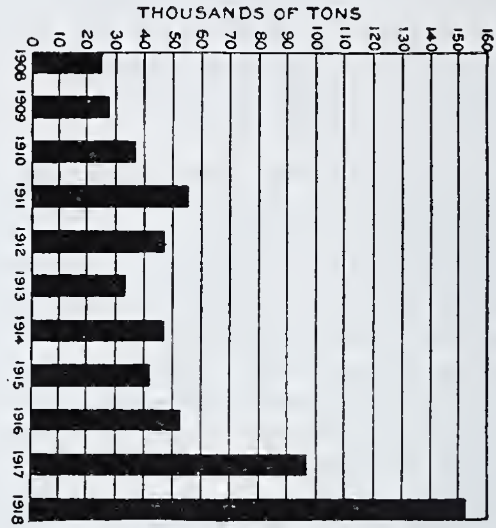

Diagram showing development of the domestic peat industry, 1908-1918.

Crude Air-dried Peat Produced in the United States, 1908-1918.

Year.	Quantity (short tons).	Year.	Quantity (short tons).
1908	a24,800	1914	47,093
1909	29,167	1915	42,284
1910	37,024	1916	52,506
1911	55,143	1917	97,363
1912	47,380	1918	151,521
1913	33,260		

aEstimated.

Crude Air-dried Peat Produced in the United States in 1918, by States.

State.	Quantity (short tons).	State.	Quantity (short tons).
Massachusetts	18,500	New York	3,501
New Jersey	70,228	aOther States	59,292
			151,521

aIncludes California, Connecticut, Florida, Georgia, Illinois, Indiana, Maine, New Hampshire, North Carolina, and Pennsylvania.

PEAT PRODUCTS.

Fertilizer.

The largest and most successful branch of the peat industry is engaged in the production of peat for a direct fertilizer and for a nitrogenous ingredient of commercial fertilizers. Of the 25 plants that produced peat in 1918, 19 used air-dried peat in the manufacture of fertilizer, the quantity of peat utilized, as reported to the United States Geological Survey, being 79,573 short tons. Compared with the output in 1917 this quantity is less by 12,690 tons, or about 14 per cent, but it exceeds the quantity used in 1916 by 31,467 tons, or about 65 per cent.

The average price received for the peat in 1918 was $9.74 a ton, a gain of $2.60 a ton over the average price received in 1917. Though there was a slight decrease in output in 1918, the increase in price was sufficient to make the total market value of the production, amounting to $775, 313, exceed the value of the output in 1917 by $116,813, or nearly 18 per cent.

Of the total quantity of peat used in manufacturing fertilizer in 1918, 7,356 tons, valued at $64,170, or about $8.72 per ton, was bacterized.

The increasing arceage of land tilled, the shortage and high price of commercial fertilizers, and the better understanding of the nature of peat, of crop adaptations, and of soil bacteriology in recent years warrant the prediction that the peat-fertilizer industry will soon reach a high position among the mineral and allied industries of the United States related to agriculture. Successful machinery for producing peat fertilizer is referred to on page 342 of this report.

Air-dried Peat Used in Manufacturing Fertilizer in the United States, 1908-1918.

Year.	Quantity (short tons).	Average price per ton	Value.	Year.	Quantity (short tons).	Average price per ton.	Value.
1908.....	23.000	$5.27	a$121,210	1914.....	37,729	$6.62	$249,899
1909.....	26,768	4.44	118,891	1915.....	38,304	6.75	258,447
1910.....	37.024	3.79	140,209	1916.....	48,106	7.00	336,004
1911.....	51,733	4.97	257,204	1917.....	92,263	7.14	658,500
1912.....	41,080	4.53	186,022	1918.....	79,573	9.74	775,313
1913.....	28,460	5.96	169,600				

aEstimated.

Stock Food.

The quantity of peat used in manufacturing stock food in the United States in 1918 was 7,096 short tons, valued at $106,935, or an average price of $15.07 a ton. Compared with 1917, the output in 1918 was greater by 1,996 tons, or 39 per cent, and the value was greater by $55,535, or 108 per cent. Four peat producers manufactured stock food in Illinois and New York in 1918, compared with three in 1917.

Air-dried Peat Used in Manufacturing Stock Food in the United States, 1912-1918.

Year.	Quantity (short tons).	Average price per ton	Value.	Year.	Quantity (short tons).	Average price per ton.	Value.
1912.....	3,000	$6.00	$18,000	1916.....	4,300	$ 7.50	$ 32,250
1913.....	4,800	5.75	27,600	1917.....	5,100	10.08	51,400
1914.....	(a)	....	(a)	1918.....	7,096	15,07	106,935
1915.....	3,980	7.56	30,090				

aNot available.

Fuel.

Several of the experimental peat-fuel plants in the New England States mentioned in the survey report for 1917[1] reached the stage of commercial production in 1918 and contributed 20,257 short tons of air-dried peat, valued at $164,-745, or an average price of $8 a ton, to the country's fuel supply. Some hand-cut peat was produced by the owners of small bogs for home use, but this output is not included in the figures given. Though the output of peat fuel in 1918 was relatively small and was due largely to the coal shortage, it exceeded the quantity produced in all preceding years and indicates that the New England States, because of their cold climate, extensive manufacturing industries, large population, and the high cost of coal, offer promising possibilities for the development of a successful peat-fuel industry. Most of the producers in 1918 used the air-drying machine process. It is understood that peat fuel machinery, which was scarce in the United States in 1918, may now be readily obtained. A description of the methods of manufacturing peat fuel that have been most successful both in Europe and in this country is given in Bureau of Mines Bulletin 16.

[1]Osbon, C. C., Peat: U. S. Geol. Survey Mineral Resources, 1917, pt. 2, p. 260, 1918.

Peat Fuel Produced in the United States, 1908-1918.

Year.	Quantity (short tons).	Average price per ton	Value.	Year.	Quantity (short tons).	Average price per ton.	Value.
1908.....	900	$9.00	$8,100	1914.....	1,925	3.40	6,540
1909.....	1,145	3.62	4,145	1915.....	....	....	....
1910.....	....	....	....	1916.....	....	....	....
1911.....	300	5.00	1,500	1917.....	....	....	....
1912.....	1,300	3.46	4,500	1918.....	20,567	8.00	164,746
1913.....	....	....	....				

OTHER PRODUCTS.

Large quantities of peat or sphagnum moss were produced and utilized in this country in 1918 for stable litter, packing material, and surgical dressings, and several hundred thousand acres of peat soils were also used for the growth of both general and truck crops. It is understood that the stable litter was produced by the owners of small bogs for their own use, but that the packing material was sold to florists and nurserymen. According to J. W. Hotson,[1] under whose direction peat moss was collected in the Northwestern States for surgical use, 595,540 peat moss pads were prepared from October, 1917, to November 11, 1918, by the Northwestern and Atlantic division of the American Red Cross. Most of the moss was gathered by volunteer labor from the bogs of Washington, Oregon, and Maine, and the pads were used in military hospitals both at home and abroad. At first the surgeons of the United States Army were not disposed to use the pads, but later the value of sphagnum was universally recognized. The gathering of moss and preparing of pads was largely curtailed when the armistice was signed, but it seems that the value of peat moss as an absorbent and disinfectant demonstrated during the war will not be forgotten and that it should be able to compete commercially with cotton for these purposes in normal times. A brief discussion of the best kinds of peat moss and of the method of gathering it is given in the report by Hotson.[1] As the quantity and value of the peat moss produced in 1918 and used for surgical dressings could not be ascertained, it is not included in the accompanying tables.

CONDITIONS IN PRINCIPAL STATES.

California.—Peat was produced by two companies in San

[1]Hotson, J. W., Sphagnum from bog to bandages: Washingtan University Puget Sound Biol. Sta. Pub., vol. 2, No. 47, pp. 213, 243, 1919.

Bernardino County, Calif., in 1918, and was used for the cultivation of citrus trees. One of these companies enriched its product by treatment with nitrifying bacteria. It is reported that treated peat, known locally as "humus," is gaining favor in the citrus industry of California and that two new peat plants were erected in 1918 but had not reached the stage of commercial production at the end of that year. No response was received to statistical inquiries directed to the Pacific Peat Fuel Co., San Francisco, Calif., mentioned by the Survey in 1917[2] as experimenting with the Herbein briqueting process. Muck soils are used to a small extent in farming California.

Connecticut.—Edward A. Beals, of Hartford, Conn., has made many energetic attempts to establish a peat industry in Connecticut, but although the State contains large deposits and plants have been erected, no market for peat fuel has thus far been created. Several years ago a peat plant was installed by the Connecticut Co., a subsidiary organization of the New York, New Haven & Hartford Railroad Co., at its Burrville power house, but after several trials the project was abandoned. A. N. Pierson, a florist of Cromwell, Conn., also attempted to substitute peat for coal in heating his greenhouses, but the raw peat selected contained an undue proportion of silica, which melted in the furnace and interfered with the draft. However, it is understood that a further effort is being made to produce peat fuel commercially in Connecticut, and it is hoped that the project will be successful.

Florida.—Two companies, one near Pablo Beach and the other at Citra, have manufactured peat fertilizer commercially in Florida for many years. In 1918, however, because of the shortage and high cost of labor, the former plant discontinued operations and the latter, operated by the Alphano Humus Co., of New York, N. Y., contributed the only peat that entered the markets from Florida in 1918. Prospective producers were hampered by inability to obtain necessary machinery. Reclaimed peat land is widely used by the agricultural industry of Florida.

Georgia.—Peat was produced in Georgia in 1918 by two plants located at Pineora and Tifton. The work was largely experimental, but it is said that the market for peat in Georgia is excellent, and that machinery is being installed in these plants to produce a large quantity of peat fertilizer in 1919.

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[2]Osbon. C. C.. Peat: U. S. Geol. Survey Mineral Resources, 1917, pt. 2, p. 260, 1918.

Illinois.—As in previous years, two operators in Illinois contributed to the output of fertilizer and stock-food peat in 1918. One of them produces more stock-food peat than any other peat operator in the United States and is second in the production of fertilizer peat. Truck crops are extensively raised on the peat soils of Illinois, and tough peat-marsh grasses are harvested and used for the manufacture of rugs and for packing ice.

Indiana.—The contribution of Indiana to the peat industry of the United States in 1918 consisted of fertilizer peat produced from bogs near Fort Wayne and Lakeville by the Virginia-Carolina Chemical Co, and the St. Joseph Humus Co. The output of the former company was used in the manufacture of commercial fertilizer, but the latter's production was sold to florists and golf clubs as a direct fertilizer for potting plants and for use on lawns. The plant of the Virginia-Carolina Chemical Co., at Fort Wayne, Ind., was destroyed by fire in 1918. Large crops of celery, onions, and other truck crops are grown upon reclaimed peat land in Indiana.

Maine.—The output of peat in Maine in 1918 consisted of a small quantity of fuel produced by one operator near Lewiston, Androscoggin County, and sold locally. Others stated that they were awaiting the results of the experimental work of the Canadian Government at Alfred, Ontario, prior to erecting plants. A small quantity of peat moss was also gathered from the bogs of Maine in 1918 and used by the American Red Cross in the preparation of surgical dressings.

Massachusetts.—The output of air-dried peat in Massachusetts in 1918 amounted to 18,500 tons, valued at $160,200, and consisted of both fertilizer and fuel produced from bogs near Peabody, North Adams, and Shirley. One producer reported that some consumers were doubtful of the value of peat fuel; another stated that the demand exceeded the supply. It is understood that several companies were organized in 1918 but did not complete preliminary work in time to contribute to the State's output in that year. C. D. Jenkins, of Boston, has been one of the most active peat producers in Massachusetts for many years and has designed and patented peat-fuel machinery.

Michigan.—Although no peat was sold in Michigan in 1918, large-scale experimental work was done by Louis P. Haight, of Muskegon, who proposes to produce bacterized peat and use it in tilling sandy soil. A large peat-fertilizer plant was erected by the Fertile Chemical Co. at Chassell, Mich., in

1918. Though this company did not produce peat that year, it will probably contribute a substantial quantity of fertilizer to the output in 1919. To meet the demand for peat-fuel machinery in 1918 plans were designed and machinery was manufactured by the C. A. Willmarth Co. and J. Campbell Morrison, of Detroit, Mich., and by Herbert Garnett, of Grand Rapids, Mich.

Minnesota.—Although Minnesota contains almost half of the workable peat in the United States, no peat products were manufactured in that State in 1918. It is understood that the Hamm Brewery Co., of St. Paul, F. A. Wildes, the State superintendent of mines, and Henry W. Hindshaw, of Hibbing, experimented with peat in 1918. Attempts are being made to obtain funds from the State legislature for experimental work on peat in cooperation with the United States Bureau of Mines. A process was reported by Mr. Wildes by which peat, when mixed with fine iron ore and flue dust and burned, produces an ore of good texture. It is stated that the process will be tried on a large scale if funds can be obtained. Peat soils are extensively utilized in Minnesota for the cultivation of crops.

New Hampshire.—The contribution of New Hampshire to the output of peat products in 1918 consisted of a small quantity of peat moss gathered from a bog 25 acres in area and 10 feet deep, near Milford, Hillsboro County.

New Jersey.—The output of crude air-dried peat in New Jersey in 1918 amounted to 70,228 short tons, of which 26,213 tons, valued at $264,797, was used in the manufacture of fertilizer, and 44,010 tons, valued at $96,040, was placed in storage. Although peat is found in Bergen, Essex, Hudson, Mercer, Middlesex, Morris, Passaic, Somerset, Sussex, Union, and Warren counties, the entire output in 1918 was obtained by four producers from deposits in Sussex and Warren counties. More peat is produced in New Jersey than in any other State, and the largest producer is the Alphano Humus Co., of New York, N. Y. New Jersey supplies the New York markets with large quantities of truck crops produced by the cultivation of peat soils.

New York.—Approximately 3,501 tons of air-dried peat, valued at $49,430, was produced by four operators in Dutchess and Suffolk counties, N. Y., in 1918, and used largely for the manufacture of fertilizer. Many of the largest truck farms in New York consist chiefly of drained peat lands.

North Carolina.—The contribution of North Carolina to the peat industry consisted of a small output produced by

one operator from a deposit 250 acres in extent near Newbern, Craven County, and sold to a company in Richmond, Va., for the manufacture of bacterized peat. It is understood that the deposit was purchased by the Richmond company in February, 1919.

Pennsylvania.—Pennsylvania contributed a small quantity of peat from a bog near Espy, Columbia County, in 1918.

Other States.—Oregon and Washington contributed the mass of the peat moss that was used by the American Red Cross in the preparation of surgical dressings in 1918. In addition to the States mentioned in which truck crops are raised on peat soil Iowa, Ohio, and Virginia contain large areas of reclaimed peat land that is used by farmers for trucking.

IMPORTS.

In previous years peat moss has been imported into this country from Canada, Germany, and Holland, but in 1918, because of the shortage of ships, no peat moss from foreign sources entered the country. The decline in imports since 1913 recorded in the following table was probably caused by the war, and it is believed that with the return of normal conditions the import trade of the moss industry will be resumed.

Peat Moss Imported for Consumption in the United States, 1913-1918.

Year.	Quantity (short tons).	Average price per ton	Value.	Year.	Quantity (short tons).	Average price per ton.	Value.
1913.....	10,983	$5.07	$55,719	1916.....	3,042	$9.16	$27,859
1914.....	9.921	5.80	57,542	1917.....	506	9.81	4 966
1915.....	7,514	6.41	48,142	1918.....	....	....	....

EXPORTS.

No exports of crude peat or peat products were reported in 1918.

CONSUMPTION.

It is estimated that 107,261 short tons of crude air-dried peat was used in 1918 for the manufacture of fertilizer, stock feed, fuel, and other peat products, compared with 97,869 tons in 1917. As the crude peat and peat products were produced by the same operators no accurate value can be assigned to the raw material. The quantity of peat actually consumed in the United States is not susceptible of accurate determina-

tion on the basis of the statistics collected by the Geological Survey. However, as no peat is exported from this country, so far as can be ascertained, and as very little is held in storage, the sum of the quantity produced and the quantity imported provides an approximation of the quantity consumed that is not without value in the absence of more specific data.

Air-Dried Peat and Peat Moss Used in the Manufacture of Peat Products in the United States in 1917 and 1918.

Kind of product.	Sales		Imports		Total	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1917.						
Sterilizer and fertilizer ingredient	92.263	$658,500	....	....	92,263	$658,500
Mock food	5,100	51,400	....	....	5,100	51,400
Foss	....	....	506	$4,966	506	4.966
	97,363	$709,900	506	$4,966	97,869	$714.866
1918.						
Fertilizer and fertilizer ingredient	79,573	$775,313	....	....	79,573	$775,313
Stock food	7,096	106.935	....	....	7,096	106,935
Fuel	20,567	164,745	....	....	20,567	164,745
Miscellaneous ...	25	250	....	....	25	250
	107,261	$1,047,243	....	....	107,261	$1,047,243

STOCKS.

Approximately 44,260 short tons of crude air-dried peat and peat products remained in storage in the United States at the end of 1918. In general peat products are marketed as quickly as possible, and hence only small quantities are kept in stock, but crude peat, because it can not be economically excavated and handled out of doors in wet or cold weather, must be produced during the air-drying season, which begins in April and ends in October. Sufficient raw material must therefore be produced in that period to supply peat-drying plants for about five months.

COMMERCIAL FACTORS.

A full discussion of the factors controlling the profitable utilization of a peat deposit is here given in order to indicate the causes of past failure. Some attempts made in this

country to produce peat on a commercial scale have not been successful, but the failures appear to have been due not to a lack of market for the product, but to the lack of sufficient capital, to the inexperience of operators, and to the injudicious choice of deposits, plant sites, manufacturing processes, and machinery. All these factors should be carefully considered by prospective producers.

Location.

The location of the deposit is the prime factor in the successful operation of a peat plant. Many deposits containing peat suitable for commercial use are known in all the peat areas, but under present conditions in the United States only deposits located near the markets and where cheap labor and transportation may be obtained can be profitably developed. Thus the conditions for producing peat fuel successfully are most favorable in Minnesota, Wisconsin, northern Michigan, and the New England States, regions which contain no known coal fields and which, because of their cold climate and extensive manufacturing industries, consume large quantities of fuel. In the southern part of the Atlantic coastal region there are likewise no local sources of other mineral fuels, but the climate is mild and the demand for fuel relatively light compared with that in the Northern States. (See Pl. III.) Peat fertilizer plants should preferably, of course, be located near the agricultural districts and the largest commercial fertilizer plants. As peat is not well known in this country, a market will have to be created in many places, but if high-grade products can be sold at a low price it should be possible to build up successful industries.

Quantity and Quality.

The prospective deposit should be carefully surveyed to ascertain whether it contains a sufficient quantity of good peat before plans are made for the erection of a plant. Typical samples should be analyzed to ascertain whether the peat is of suitable quality for the purpose desired. One of the great handicaps of the peat industry has been the lack of uniformly good quality, and, as the success of a plant depends upon the kind of raw material used, due care should be observed in its selection.

The requisite size of the deposit will, of course, vary with the capacity of the plant erected, but it is generally unwise to erect a plant on a deposit less than 100 acres in area and 4 feet in depth. The average peat deposit will yield approximately

200 tons of air-dried peat to the acre foot. The product obtained by multiplying the area in acres by the depth in feet by 200 gives the approximate tonnage of peat in a deposit. The topographic maps issued by the United States Geological Survey show many important peat deposits in this country as swamps and marshes, the area of which may be readily estimated from the map. The dimensions of deposits that have not been mapped should be carefully measured. Although peat deposits less than 4 feet deep may be advantageously used for the growth of crops, they are of little value as a source of fertilizer or fuel. Numerous depth tests should therefore be made and the average thickness of the peat determined. An earth auger may be employed for this purpose, but a sapling tool especially designed by the late C. A. Davis[1] for testing the depth of peat deposits is superior to the earth auger for sampling peat.

Samples of peat should typify the entire deposit from which they are taken or a definite portion of it. Specimens consisting of material taken at depth intervals of 1 foot and at areal intervals of 100 yards in a small shallow deposit are usually adequate to represent the general composition of the deposit. It is obviously impossible to obtain a typical sample of the peat in a large deep deposit. Such a deposit should be divided into blocks and typical samples should be obtained from each block. In large deposits samples are generally taken at depth intervals of 2 feet and areal intervals of a quarter of a mile. The material taken in each block may later be mixed in order to obtain a representative composite specimen. Structural features should be noted as deposits are sampled, and if the peat is distinctly bedded, samples should be taken from each bed and separately analyzed. If the lower strata contain a large proportion of inorganic impurities, that fact should be noted, in order that these strata may be avoided in excavation. As analyses of dry peat show its chemical composition and fertilizer and fuel values as well as analyses of wet peat, it is unnecessary to place samples taken for analyses in air-tight containers. For a simple test about 10 pounds of raw peat is required, and for a detailed chemical analysis about 40 pounds. Samples should ordinarily be air-dried to a moisture content of about 50 per cent in the field and sent to the laboratory in canvas bags. However, if it is desired to identify the plant remains, small specimens should be placed in

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[1]Davis. C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, p. 71, 1911.

sealed bottles or air-tight cans so that the peat may later be examined under the miscroscope in its native condition.

Black, thoroughly decomposed, friable peat from a deposit that has been well drained, aerated, and successfully cultivated for several seasons is usually suitable for an ingredient of commercial fertilizers or, when inoculated with nitrifying organisms or composted with manure, for a direct fertilizer.

Some evidence of the fuel value may be obtained from a small sample that has been macerated in the hands, pressed into a cake, and allowed to dry in the sun. If it is easily disintegrated and plastic while wet, it may be readily worked in a peat machine, and if, when dry, the cake is dense, tough, and hard, the peat will probably make good fuel unless the ash content is too high. However, if the dry peat cake is soft, fibrous, and easily crushed, the peat is not well adapted to the manufacture of fuel.

The heating value and ash content of prospective peat fuel for home consumption may be determined by a simple practical test. A typical sample should be taken from the bog, thoroughly macerated, dried, and weighed. If when burned in an ordinary heating stove the heat generated is a little less than that produced by ordinary bituminous coal, and if after complete combustion the weight of the accumulated ash does not exceed 20 per cent of the weight of the dry peat put into the stove, its usefulness as domestic fuel is established.

Preparation of Surface.

The surface of peat deposits must be prepared by draining and clearing before the peat can be removed. The water level should be reduced by a system of tile drains or ditches to a point between 2 and 3 feet below the surface. Only deposits that can be cheaply drained should be selected. Many bogs are easy to drain, but the drainage of some peat-forming basins is so difficult that their surfaces can not be economically prepared for peat production by known methods. Marsh deposits and bogs are cleared by removing the living grasses and mosses and grubbing out the shrubbery. The clearing of swamps overgrown by mature trees is expensive, but this expense is sometimes offset by the value of the timber obtained.

Process and Machinery.

The failure of many peat plants in the United States has been due to improper choice of manufacturing processes and machinery. The excess moisture in the peat must be elimin-

ated at as early a stage as possible in the manufacturing process. This can be most economically done by evaporation on the surface of the deposit. Whether for the manufacture of fertilizer or fuel, machinery of proved efficiency must be selected. Field equipment propelled by caterpillar drives seems well suited for use on boggy surfaces. The most successful peat-fuel machinery that has been used in North America was designed by the Canada Department of Mines and recently operated at Alfred, Ontario. Mr. John N. Hoff, of New York, N. Y., is the inventor of peat-fertilizer machinery that has been successfully used by him on a deposit near Great Meadows, N. J., for several years. Experimental work is always commendable if properly limited, but the methods and machinery that have proved successful in North America and in the peat-producing countries of Europe should be given first consideration. The peat industry of European countries is well developed, and detailed information concerning European peat machines is available in Bureau of Mines Bulletin 16 and in the report of the Canada Department of Mines cited on page 350.

Markets.

The principal markets for fertilizer peat are in or near some of the agricultural States. notably Maryland, New York, New Jersey, Illinois, Virginia, Kentucky, Tennessee, and Florida, and the largest buyers are the manufacturers of commercial fertilizer, brokers in fertilizing materials, florists, and farmers. Markets could probably be created in all the agricultural States. Stock-food peat is sold to manufacturers of stock feed and to growers of live stock. Many of the peat deposits in this country are located in regions remote from the coal fields, and it seems that markets for peat fuel might therefore be created in some of the peat States.

DEFINITIONS.

The terms "peat" and "muck" are often used interchangeably to designate either of those materials. This practice is confusing and should be discouraged. Peat is the partly carbonized organic residuum produced by an arrest in the decomposition of roots, trunks, and leaves of trees, twigs, shrubs, mosses, and other vegetation covered or saturated with water. It contains a large proportion of the carbon of the original vegetable matter, and in most peats the vegetal structure is visible without the microscope. Peat is usually acidic, and the quantity of inorganic matter is materially

less than that of the organic, pure peats often containing less than 4 per cent of inorganic impurities. Muck is uncarbonized organic soil containing a large proportion of inorganic mineral. However, it is difficult to define the line of demarkation; peat may grade into muck and muck into peat. If the material will ignite and burn freely when dry it is usually considered peat.

ORIGIN.

The formation of peat is dependent on conditions favorable to the profuse growth of plants and to the escape of the plant debris from complete decomposition by bacterial and chemical action, conditions which are governed by topography and climate. If the land surface contains depressions, flat or gently sloping, poorly drained areas in which water may collect and permanently stand, and if the temperature of the air and the soil is low in summer or the humidity of the air is high enough to prevent rapid evaporation, peat-forming plants will flourish.

Glaciation was the dominant factor in the distribution and origin of most of the peat deposits in this country as well as of many in Canada and Europe. These deposits for the most part occupy lakes, marshes, and ponds formed during the last glacial epoch. Another factor in the distribution of peat is the character of the surface rock, which in many regions determines the topography. When the earth's surface, composed of rock formations that vary in hardness, is subjected to stream or glacial action, surface depressions develop. Some of the peat deposits of the New England States owe their origin to this diversity of surface rock. Basins in which peat may accumulate are also formed in a few limestone regions by solution.

Next in importance to glaciation in peat formation are wave and stream action and coastal subsidence. Many peat deposits of salt and fresh-water origin are found in drowned valleys where the coast has subsided and land-locked lagoons have been formed behind barriers by wave action or where deltas have been built up and the coast has subsequently risen, resulting in the formation of flat, imperfectly drained inland areas. In some places salt-marsh peat underlies peat of fresh-water origin and in others the reverse, indicating the fall and rise of the seacoast.

Abundant and evenly distributed rainfall, high humidity, and a cool or moderate temperature are the most favorable climatic conditions for fresh-water peat formation. All these conditions are present in the northern peat region and in

varying degrees in the coastal region. Peat sometimes forms in the Frigid Zones, but not extensively, and also in the Torrid Zone, although owing to the high temperature, plant debris decays there rapidly, and despite profuse plant growth peat accumulates slowly and therefore contains a high percentage of inorganic matter. For good tropical peat a heavy rainfall well spread through the year is essential.

On account of the good drainage no peat of consequence is found in the Appalachin and Rocky Mountain regions, nor, because of scanty rainfall, in the area between the Rocky Mountains and Mississippi River, except in Minnesota and Iowa. Contrary to the general belief, there is little peat in commercial quantities in the lower Mississippi Valley, a condition due partly perhaps to high temperature, but mainly to the vast amount of alluvium carried and deposited from time to time by Mississippi River and its tributaries.

Although hundreds of different plants have been identified in the bogs and swamps of this country, comparatively few contribute the mass of the vegetable debris from which peat forms. The most common are trees, heath, shrubs, sedges, grasses, mosses, pondweeds, water lilies, reeds, cattails, and ferns. When given a favorable environment most of these plants multiply rapidly and soon predominate over their competitors; in fact, in some areas they grow so densely that man penetrates them with difficulty, and an immense quantity of dead vegetation accumulates annually.

One of the chief substances formed by plants during growth is cellulose, which consists of carbon, hydrogen, and oxygen. These constituents are absorbed by the leaves from atmospheric gases and by the plant roots from the soil. Cellulose, because of its complex composition, is an unstable compound and when attacked by fungi and bacteria rapidly decomposes. If at the end of the growing season the plant debris falls upon drained soil, it is vigorously attacked by these microorganisms, and the carbon and hydrogen of the cellulose unite with the atmospheric oxygen and with each other, forming carbon dioxide and water. In other words, if oxidation is unhampered, the organic matter will disappear in a relatively short time. If, however, the plant matter falls in large quantities into water or upon soil saturated with moisture, it undergoes a different change from the decay suffered by exposed vegetation. The atmospheric oxygen is largely excluded and as the activity of fungi and bacteria, which usually cause complete decay, is controlled by the supply of air, upon which they depend for their existence, decay is slow, and a large proportion of the fixed carbon is re-

tained. The salient features in the evolution of peat from cellulose are the elimination of hydrogen and oxygen as water and of carbon and oxygen as carbon dioxide and the generation of methane. This is the process of carbonization.

If surface conditions are unchanged the process of carbonization is largely arrested with the formation of peat, and the accumulation of organic matter may exist indefinitely as peat unless the land is drained and decomposition again begins. If, on the other hand, the peat is deeply buried beneath superposed deposits, generally muds, sands, and limestone, and is subjected to pressure, with varying degrees of heat, lignite, bituminous coal, anthracite, and graphic are sunceeding stages in the process of carbonization. It seems, therefore, that most coals of the common types were once peats, that most coal fields were formerly swamps, and that the formation of peat in the bogs and swamps of this country is an existing example of the first stage in the process of coal formation. It has been shown that deposits essentially similar were laid down in many parts of the United States during the Carboniferous period.

DISTRIBUTION AND QUANTITY.

The most extensive deposits in the United States are found in a region which lies east of the ninety-seventh meridian and north of an irregular line drawn eastward through the northern sections of Iowa, Illinois, Indiana, Ohio, Pennsylvania, and New Jersey, and approximately includes the area covered by the Wisconsin or last glacial drift. Many workable peat beds occur also in areas extending 25 to 50 miles inland on the Atlantic coast from New Jersey to southern Florida and along the gulf coast to the Mexican boundary, and there are a few workable beds of peat in the Pacific Coast States.

The areas of peat accumulation in this country may, therefore, be roughly assigned to two major regions, the northern or glacial and the coastal, and this subdivision, though partly geographic, expresses the chief differences in manner of formation and in the quality of the peat. The northern peat region includes Minnesota, Wisconsin, Michigan, New York, northern New Jersey, the New England States, and the northern sections of Iowa, Illinois, Indiana, Ohio, and Pennsylvania. This region is characterized by the presence of numerous small lakes and marshes formed as a result of glacial action during Pleistocene time and by relatively low temperature and high humidity, and most of the

peat originated in basins. Moss sedge, grass, and tree peat are abundant, and much sphagum is found growing on bogs in Maine and in the northern counties of Minnesota, Wisconsin, and Michigan. The deepest and most extensive deposits in the New England States lie east of the Berkshire Hills and the Green Mountains.

The Atlantic coastal region embraces southeastern New Jersey, the eastern parts of Delaware, Maryland, Virginia, North Carolina, South Carolina, and Georgia, all of Florida, the southern parts of Alabama, Mississippi, and Louisiana, and coastal Texas. The nearness of the ocean causes heavy rainfall and high relative humidity in this region, and the deposits are found in drowned valleys and lagoons formed by the gradual subsidence of the Coastal Plain and by wave action and on flat, imperfectly drained areas farther inland. The region is typified by many fresh and salt water marshes and by swamps in which the deposits have been formed largely by trees, marsh grasses and other plants, some of which tolerate salt water around their roots. On the Gulf coast, owing to the hot climate, dead vegetation decays rapidly, and as the peat therefore accumulates slowly it contains much ash. The most extensive deposits in the coastal region occur in Florida.

Although there are a few peat deposits on the New England coast that are related in origin and composition to those classed in the coastal region, by far the most numerous bogs of the northeastern States are of the glacial-lake kind, and the region as a whole should be so considered in a classification of the major peat regions.

The known workable peat beds of the Pacific coast region occur in Orange, Los Angeles, and San Bernardino counties, Calif., and in the basins of several of the lakes and rivers of Washington and Oregon, but peat deposits of commercial extent are comparatively rare in this region.

The total quantity of good peat in the United States, exclusive of Alaska, was estimated in 1909 to be about 12,889,000,000 short tons,[1] but recent field investigations by E. K. Soper and others seem to justify an increase of this figure to 13,826,000,000 tons.

[1]Davis, C. A., Peat resources of the United States exclusive of Alaska: U. S. Geol. Survey Bull. 394, pp. 65-66, 1909.

Approximate Distribution and quantity of Air-Dried Peat in the United States.

	Short Tons.
Northern region	11,053,000,000
Atlantic coastal region............	2,701,000,000
Other regions	72,000,000
	13,826,000,000

USES.

War-Time Uses and Possibilities.

A review of conditions in the peat industry during the year in which the great world war terminated seems a fitting place to record the war-time uses and possibilities of peat and its relation to the welfare of a warring nation. Peat and peat moss are used in the manufacture of fertilizer, fuel, and surgical dressings, products which, though necessary in time of peace, are vital in time of war.

Peat was extensively utilized in nearly every European country during the war to supplement inadequate supplies of coal and fertilizer, and many governmental plants were erected for its production. In some countries prices were fixed to prevent extortion and measures were adopted by the Governments to stimulate production. As imports of coal into some countries were greatly curtailed, much suffering and financial loss resulted, despite the large output of peat from domestic sources, but because of this increased production of peat fuel, which was extensively used by domestic consumers and in hospitals, great hardship was avoided by some people and many lives were saved.

The collection of sphagnum, or peat moss, was another important war activity that assumed large proportions in Europe. The gathering of surgical moss by volunteer labor was considered a patriotic duty in England and Scotland, and before the armistice was signed the question "Are you gathering moss?" assumed the nature of a byword. Millions of moss pads were used during the war, and the supply of cotton available for the manufacture of munitions was thus greatly augmented.

In the United States, on account of our immense coal reserve and large output of cotton, peat did not take a large part in war activities, but by furnishing nitrogen to the fertilizer industry it released nitrates for the manufacture of explosives, and was thus of some assistance in the prosecution of the war. More than half a million peat-moss pads

were prepared in this country and sent to domestic and foreign military hospitals. It is understood that a plant for the manufacture of nitrate from peat was in process of erection when the armistice was signed. Shortly after this country entered the war the United States Geological Survey directed attention to the vast peat deposits of this country located in regions remote from the coal fields and suggested the production of hand-cut peat fuel for local use by the owners of small deposits. It appears from reports that many people responded and that more peat fuel was produced in the United States in 1918 than in all preceding years. Our peat deposits are of great potential value as a source of fuel, fertilizer, nitrate, and antiseptic material.

PEAT IN AGRICULTURE.

Fertilizer.

The peat deposits of the United States are one of the few extensive known domestic sources of nitrogen that can be converted into plant food at a price that is economical to the farmer. The average nitrogen content of domestic raw peat is about 2 per cent, although many peats contain more than this quantity. The nitrogen may be recovered in the form of ammonium sulphate or may be made available for plant food without extracting it from the peat. Arguments are often advanced against the direct use of peat as a source of nitrogen in soil fertilization because all of this element shown by chemical analysis is not readily available for plant food, but this criticism seems to be based on a misconception of the nature of peat. It is true that only a part of the nitrogen shown by analysis can be immediately used for food by plants, but it is equally true that a chemical analysis of peat is not a fair test of its value as a fertilizer and that the total quantity of potential soluble nitrogen formed and released by bacterial action from time to time after the peat has been applied to the soil is in the aggregate much greater than the percentage found in some commercial fertilizers.

Fortunately all of the nitrogen in peat is not soluble at one time, or it would leach out and the potentially rich black peat soils of this country would be unproductive.

The largest use of peat in the United States for the cultivation of crops, exclusive of the direct cultivation of peat soils, is in the form of a nitrogenous ingredient of commercial fertilizers. In fact some of the large manufacturers of com-

mercial fertilizer rely on peat to contribute a substantial proportion of the nitrogen content of their product. It is said that good peat when properly prepared for this purpose will contribute nearly 5 per cent of its total weight as nitrogen.

A new process for the commercial application of bacteriology to soil fertilization was reported in 1918 by John N. Hoff, of New York, N. Y. According to his method the peat is cultivated for several seasons, excavated, air-dried, neutralized or made slightly alkaline, and is used as a carrier and energizer of several varieties of legume and other bacteria.

Peat Soils.

Peat soil when properly treated is one of the most fertile types of soil in this country. Owing to the abundance in previous years of well-drained land that could be more readily tilled, the peat and muck areas have been passed by; but with the rapid increase of our population and the advent of intensive soil cultivation the attention of agriculturists and others is now being directed to these neglected lands. In the eastern section of this country there is approximately 15,000,000 acres of peat and muck land supporting a growth of shrubs, tamarack, white cedar, birch, water maple, gum, and cypress, and only about 750,000 acres, or 5 per cent of the total area, has been reclaimed for agriculture. Secretary Franklin K. Lane, in advocating the reclamation of the swamp and cut-over timber lands of the United States and their sale on deferred payments to discharged soldiers, sailors, and marines, said in substance in a recent statement for the press:

> There are approximately 200,000,000 acres of cut-over or logged-off timber land in the eastern half of the United States and, overlapping to a certain extent the cut-over lands, some 80,000,000 acres of swamp land located largely in the southeastern section of the country.
>
> To the ordinary observer the reclamation of these waste areas may seem difficult. The soil, however, is in many instances very fertile. For many years leaf mold containing humus has been accumulating, and once the stumps have been blown out and the land cleared of brush and brought under the plow, it is believed that these lands will prove among the most fertile of our agricultural resources. Like the Dismal Swamp in Virginia, or the Everglades in Florida, most of the swamp land in its present condition is unfit for human habitation. Consider this land cleared of its timber, adequately drained, and intensively cultivated, and some idea of its possibilities for the production of food will be obtained

Raw peat soils, though too acidic for ordinary farming, are after they have been drained, cleared, freely aerated, and properly fertilized, especially well adapted to the production

of vetch, redtop, millet, buckwheat, oats, corn, rye, the potato, the cranberry, the blueberry, the strawberry, and other acid-tolerate crops.[1] If properly treated with potash salts and with lime they are neutralized or made slightly alkaline and should then yield large quantities of red clover, timothy, blue grass, wheat, rutabagas, and other alkaline or neutral-soil crops. The greatest returns derived from the cultivation of peat, however, have arisen from its use as a truck crop soil. According to the Bureau of Soils,[2] cabbage. onions, celery, lettuce, spinnach, carrots, beets, turnips, and peppermint are the most valuable crops that are grown on treated areas of peat. The acreage values of these crops so far surpass those of the general farm crops that the reclamation of any large areas of peat should be undertaken with the special object of their production.

The fertility of peat soil is chiefly due to its nitrogen and humus contents, to its affinity for moisture, and to its black color, which enables it to absorb heat. For the profitable production and sale of both general and special crops, it is desirable that such areas of peat as are close to large city markets and accessible to good transportation and cheap labor should be first reclaimed.

The first attempts to use peat lands for the growth of crops were made in the older agricultural districts of the Eastern States, notably New York and New Jersey. Some of the most productive farm lands in those States were formerly peat bogs and swamps. The truck farm of John N. Hoff near Great Meadows, Warren County, N. J., the well-known onion farms of the Wallkill River valley, Orange County, N. Y., and the Oak Orchard lands north of Batavia, N. Y., are reclaimed peat deposits. Thousands of acres of land in these States now under intensive cultivation are underlain by peat from 10 to 15 feet deep. Nearly half a million acres of peat land in the Dismal Swamp district of Virginia and North Carolina is successfully devoted to the growth of potatoes, corn, wheat, and other crops. An average of more than 30 bushels of wheat to the acre has been obtained for several years on the well-tilled farm of the Wallace Bros., in the Dismal Swamp, Va. Peat soils are also extensively used for crop cultivation in Minnesota, Wisconsin, Michigan, Iowa, Illinois, Indiana, and Ohio. Thousands of acres are already under cultivation, and millions may be reclaimed by proper

[1]Coville, F. V. The agricultural utilization of acid lands by means of acid-tolerant crops: U. S. Dept. Agr. Bull. 6, 1913.

[2]U. S. Dept. Agr. Bur. Soils Cir. 65. pp. 13-14, 1912.

drainage and clearing. In fact, the economic future of entire counties seems to be directly dependent upon the successful reclamation of peat bogs and swamps.

Many peat soils require careful fertilization before crops can be successfully grown upon them. This is especially true of deep peat, as the plants are unable to obtain certain necessary minerals from the subsoil. Potash is required by many peats, and phosphates and nitrates by some. However, if subjected to intensive plowing and thoroughly aerated, well-decomposed peats are usually rich in nitrogen. If it is desired to raise alkaline-soil crops and the acidity of the peat can not be corrected by plowing and areation, lime should be applied.

Many peat areas in the northern or glacial region are underlain by beds of marl, a white or gray claylike variety of limestone composed largely of calcium carbonate ($CaCO_3$) brought into lakes and marshes by springs or stream waters and precipitated through the agency of blue-green algae and stone worts (Chara). The plants extract carbon dioxide from the water and thus cause the deposition of the lime held in solution. Deposits of fresh-water marl are common in the southern peninsula of Michigan, in northern Indiana, in western New York, and in northwestern Pennsylvania. Shell limestone deposited by organisms is another common kind of calcareous material frequently found beneath peat in the coastal region. Dense, fine-grained limestone, marble, travertine, oolitic limestone, and chalk, though not commonly associated stratigraphically with peat, occur in many regions near peat deposits. There are, therefore, many peat areas in this country which on account of their acidity are of little value for general farming but which could be economically treated with lime from associated or adjacent deposits and made to yield large alkaline or neutral-soil crops.

Where it has been properly used the application of lime to peat soil has resulted in increased fertility. The limestone should be ground or burned before use as fertilizer, as the lime is then available immediately, whereas if applied in an untreated condition some varieties of limestone, notably shell "marl," are relatively inactive the first year. The chemical and physical effects of liming are manifold. It releases potash from certain silicates; it promotes the decomposition of the peat, freeing soluble nitrogen; applied to sour soils, it corrects the acidity; and applied to peat soils that harden in lump form upon drying, it renders them easily workable.

PEAT FUEL.

Machine Peat.

The following data[1] based upon the experiments of the Canada department of mines show the cost of a machine peat-fuel plant and of producing air-dried machine peat in commercial quantity in Canada before the war. The cost of production was calculated from an output in five months of 3,300 short tons of fuel containing 25 per cent moisture.

Cost of 30-Ton Anrep Peat Plant.

100 acres of peat land, at $6 an acre	$ 600.00
Peat machine, locomobile, tracks, cars, cables, etc.	7,500.00
Blacksmith shop, office, loading platform, and railway siding	1,100.00
Drainage, clearing, etc	1,500.00
	$10,700.00

Cost of Producing a Ton of Air-Dried Machine Peat.

Labor and supervision	$1.21
Amortization and interest	.34
Repairs, fuel, oil, waste, etc	.15
	$1.70

Peat Briquets.

Peat briquets are usually made from raw peat that has been air dried to a moisture content of 40 per cent. After the peat has been macerated and powdered, the moisture is further reduced to about 15 per cent by artificial drying. A binder is then mixed with the peat and the mixture is compressed into cylindrical or prismatic shape by means of a piston subjected to a pressure of 18,000 to 30,000 pounds to the square inch.

Although there is a little more heating value per pound in peat briquets than in machine peat, the briquets are cleaner, more compact, greater in heating value per volume, and generally more attractive than machine peat. These advantages, however, are more than offset by the high cost of production. Artificial drying requires nearly as much heat as that obtainable from peat briquets prepared in this manner, and the cost of binders and compressing is so great that the process is of doubtful commercial value in the United States.

Peat Coke and Charcoal.

Peat charcoal was made in Europe for hundreds of years

[1]Haanel, B. F.. Peat, lignite, and coal: Canada Dept. Mines, Mines Branch, Pub. 299, p. 27, 1918.

by piling cut peat in dome-shaped heaps, covering it with soil, and burning the peat with a restricted supply of oxygen. This process is little used now and peat charcoal has been displaced by peat coke, which is manufactured in Europe by the Ziegler process.[1] According to this method the coke is produced by heating machine peat blocks in specially designed retorts. Good peat coke is equal in quality to the best grades of charcoal produced from wood. If made from blocks of well-macerated, thoroughly decomposed peat that contains little ash, peat coke is compact and hard and should be able to compete with coke manufactured from coal. Alcohol, acetic acid, ammonia, ammonium sulphate, parraffin wax, illuminating oil, phenol, and asphalt are some of the valuable by-products that may be obtained in coking peat by the dry distillation process.

Peat coke is extensively used in Europe, but in the United States, though it could probably be prepared for about $4 a ton, this material has never been commercially produced. There are large deposits of peat suitable for the production of coke within a few miles of the iron-mining districts of Minnesota, and it seems that the practicability of locating peat-coke plants in this region should receive thoughtful consideration from engineers.

There are two kinds of by-product gas-producing plants that use peat—the Mond and the Frank-Caro.[1] The same principle is applied in both and the differences between them are minor. Crushed peat is fed into a furnace in which combustion is regulated by steam and hot air. The peat burns at the bottom of the feed shaft, and, reacting upon the steam, forms water gas and ammonia. These gases are next cleansed of tar by means of a scrubber and are subjected to a fine shower of sulphuric acid, which converts the ammonia into ammonium sulphate and purifies the water gas. After being cooled the water gas may be used under steam boilers, in internal-combustion engines, and for other purposes.

It is said that at Cordigoro, Italy, peat containing 2.5 per cent of combined nitrogen, when treated by the Mond process, yielded 170 pounds of ammonium sulphate to the ton. Gas-producing plants using peat fuel have been operated in England, Ireland, Germany, Sweden, Italy, and Russia, but

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[1]Nystrom, E., Peat and lignite, p. 176, Canada Dept. Mines, Mines Branch, 1908.

[1]U. S. Geol. Survey Bulls. 290 and 332 and Prof. Paper 48; Bur. Mines Bulls. 4, 7, 9, 13, and 16. Wyer, S. S., Producer-gas and gas producers, 1907. Haanel, B. F., Peat, lignite, and coal: Canada Dept. Mines, Mines Branch, Pub. 299.

not in the United States, although experiments have been made here. Analyses of the peats of the United States show that they are rich in combined nitrogen, from 70 to 85 per cent of which—a proportion that in some peats amounts to more than 2 per cent of their dry weight—could be recovered in the form of ammonium sulphate in by-product gas-producing plants.

OTHER USES.

Packing Material.

Because of its lightness, resiliency, and antiseptic properties, peat makes excellent packing material and has long been used for packing eggs, fruit, vegetables, and fragile articles. Dry peat is a non-conductor of heat and hence is valuable in ice houses and as packing for water pipes. The best material is obtained from the fibrous types of peat consisting of partly disintegrated grasses and mosses. Peat moss is also utilized by florists and nurserymen in shipping flowers, shrubs, and plants.

Paper, Wood, and Cloth.

Peat was used a few years ago at a plant near Capac, Mich., for the manufacture of cardboard and paper. Grass and sedge peat would probably make the best paper stock, as this peat consists of strong fibrous material. It is understood that rugs are also made in this country from incipient sedge and grass peat. Peat has been successfully used in Europe for the manufacture of wall board and other artificial wood products. German and Swedish manufacturers have also made a durable yarn from a mixture of peat moss, shoddy, and wool, from which a cloth resembling cheviot is woven.

Mud Baths.

At certain health resorts in Germany and Austria peat has long been successfully used for so-called "mud baths," and during recent years experiments have been made to test the healing properties of peat in some of the sanitariums of this country. Well decomposed peat, free from coarse or woody material is the basis of the mixtures used, and it is reported that persons suffering from rheumatism and like diseases are materially benefited by the treatment.

PEAT INDUSTRY IN PRINCIPAL FOREIGN COUNTRIES.

General Conditions.

The year 1918, as a result of the rather general shortage

and high prices of coal, was one of great expansion and prosperity in the peat industry of most European countries. The quantity of peat produced and sold in some of these countries exceeded the quantity marketed in any preceding year. More peat fuel was produced than any other peat product, but the most interesting development was the world-wide use made of peat or sphagnum moss in the preparation of surgical dressings.

Russia.

Stimulated by war and the consequent shortage and high price of coal, the output of peat fuel in Russia in 1918, was approximately 10,000,000 metric tons, or almost double the quantity produced in years preceding the war. Of this quantity about 7,000,000 metric tons were manufactured in the central provinces. The sale of peat-fuel machines, which affords a fairly reliable index to the ratio of increase in production, has more than doubled in recent years.

The Electrical Transmission Co., of Moscow, which annually supplies that city with approximately 40,000,000 kilowatt hours of electrical energy by the use of peat, recently applied to the Russian Government for a loan of 8,000,000 rubles to meet the high cost of labor occasioned by the war. It is understood that the minister of trade and industry recommended that the request be granted.

Germany.

Information concerning conditions in the peat industry of Germany has been difficult to obtain during the war, but the following data furnished by Sergt. H. E. Stanley, of the American army of occupation, and made available to the survey through the courtesy of the Fertile Chemical Co., of Cleveland, Ohio, indicate that the production of peat fuel in Germany has reached a high state of development:

> Extensive peat beds, varying in depth from 1 to 17 meters, are found between Bruhl, Germany, and the Holland border. There are many plants near Bruhl and Liblau, where deep peat of good quality is found. About 35 peat-fuel plants are also located between Bruhl and Cologne and more than this number north of Cologne.
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> After the peat has been excavated, it is loaded in buckets, which are carried on aerial cables from the deposit to the plant, in some instances a distance of 2 kilometers. The raw material is run through a macerator, pressed into blocks, and stamped with the firm name. It is said that when the peat reaches the plant it contains about 80 per cent of moisture, which is reduced to 15 per cent by natural and artificial drying. As most of the work is done by machinery, little hand labor is required.

Denmark.

Conditions in Denmark in recent years have been decidedly

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[1]Am. Peat Soc. Jour., vol. 11, 2, pp. 50-53, 1918.

favorable to the expansion of the peat industry. The following table, based upon data furnished by John Olsen, of Arlington, Mass., shows the stimulating effect of the coal shortage during the war on the peat-fuel industry of Denmark:

Air-Dried Machine Peat Produced and Consumed in Denmark, 1914-1918.

Year.	Number of producers.	Quantity (metric tons).	Average price per ton.	Value.
1914	65	86,849	(a)	(a)
1915	69	95,145	$4.08	$ 388,191
1916	160	118,484	6.43	761,852
1917	564	397,846	7.70	3,063,414
1918	1,380	851,546	7.00	b5,960,822

a Not available. b Estimated.

There are two processes of producing machine peat in Denmark, the wet and the dry. According to the wet process, which is the one in most general use, water is added to the peat as it is put through the machine, and the resultant mud-like mixture is then spread out on drying fields and molded or cut into bricks by hand. This process, which originated in Denmark, produces a firm, dense brick particularly well adapted for industrial fuel. In the dry process the peat is macerated without the addition of water and cut by the machine into bricks, which are then spread out on the drying field.

Producers of hand-cut peat reported an output of 1,407,435 metric tons, estimated to be worth $9,039,178. A basic price of $7 a metric ton for peat having a combined ash and moisture content of 40 per cent was established in 1918. About 60 per cent of the machine peat produced in Denmark in 1918 was used for industrial purposes, and the cut peat was largely consumed in households. A series of tests was made with peat as locomotive fuel, and peat was used regularly on two branch lines with good results. The distances run during tests were 45 to 85 miles, and the peat consumed amounted to 6.7 pounds per car-mile.

A textile industry in Denmark, based upon peat, seems to be a prospective result of experiments recently conducted in that country.[1] It is reported that a grayish material resembling woolen cloth is woven from yarn 75 per cent of which consists of peat fiber and 25 per cent of woolen waste. Knitting machines by which hosiery was made from peat

[1]Commerce Repts., Oct. 9, 1918.

yarn were shown in 1918 at an exhibition in Goteborg. A plant for the manufacture of peat yarn has been established at Silkeborg, and other factories will probably be erected. A new corporation, known as the Dansk Mose-Industri, with a capital stock of $34,840, was organized at Aarhus, Denmark, in 1918, for the production of peat products. A peat-briquet factory is also being erected at Brondersler.

Sweden.

The output of machine-peat fuel in Sweden in 1917 was approximately 100,000 metric tons, compared with only 22,-500 tons in 1916. These figures do not include hand-cut peat produced by peasants for local use, which probably amounts to more than the output of machine peat.

A large quantity of powdered peat was used in Sweden in 1918 for the generation of steam in locomotive boilers. A description of the type of locomotive adapted to use powdered peat for fuel and of the method of operation is given in a recent report of the Department of State by the United States Ambassador at Stockholm, Sweden.

Material progress was made in Sweden in 1918 toward the development of a peat cloth industry.[1] It is said that an economical method has been devised for extracting, carding, and spinning peat fiber. Plants were constructed at Hadenge, in Jonkoping Len, and at Goteborg for the manufacture of peat cloth from which matting, felt, carpet stuff, and even clothing may be made. The plants are reported to be capable of producing peat yarn at 4 cents a pound which can hardly be distinguished from wool.

It is reported[2] that mineral oil may be extracted from the peat deposits of Sweden and that there are good opportunities in that country of thus building up a domestic oil industry. Good air-dried Swedish peat yields, by dry distillation, from 5 to 8 per cent of tar, from which motor, illuminating, and lubricating oils, paraffin, and creosote may be extracted.

Many new companies for the production of peat were organized in Sweden in 1918, the largest of which is the South Swedish Peat Industry Union, capitalized at $1,000,000, and capable of producing 12,000 metric tons of peat annually. It is estimated that Sweden contains about 12,355,220 acres of peat.

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[1] U. S. Commerce Repts., 163, p. 169, 1918.

[2] Berlingske Tidende, Copenhagen, Denmark, 1918.

British Isles.

Peat in the form of crude hand-cut blocks has been the only fuel of many Irish peasants for centuries. It is estimated that Ireland contains 3,000,000 acres of peat land, a quantity sufficient to meet the needs of that country for a thousand years. Despite this vast reserve, peat fuel was scarce in Ireland in 1918, and the price rose in some part of the country from $1.20 to $4 a horse load, or about $10 a short ton. There has been much discussion recently in Great Britain concerning the use of Irish peat as a source of fuel for the generation of electricity, and an experiment to demonstrate the potentialities of peat for this purpose was begun in 1918. It is believed that this is the most efficient use of peat that can be made, and that if peat fuel of better quality than that produced by the peasants for use in their own homes could be supplied at a low price the domestic welfare of the Irish people would be materially improved.

The following excerpt from a report[3] relating to the peat resources of the British Isles indicates that peat attracted wide attention in 1918:

> The scarcity of coal in Great Britain caused by the lack of miners raised the question in 1918 of coal substitutes, and peat was mentioned as a prospective low-grade fuel.
>
> The peat deposits of England, Scotland, and Wales have been almost untouched because of the abundance and low price of coal, but war conditions, necessitating the conservation of coal supplies, have directed attention to the larger utilization of peat for the generation of heat and power. According to the estimates of engineers who have studied the subject there are immense reserves of peat in the British Isles. The peat deposits of the United Kingdom are estimated to cover more than 6,000,000 acres and to contain material equivalent in heating value to 5,000,000,000 metric tons of anthracite coal.

Although peat fuel was not extensively used in England and Scotland in 1918, nearly 12,000,000 peat-moss pads were prepared and used in British military and naval hospitals in that year. Figures concerning the value of these pads are not available, but it is estimated that if absorbent cotton had been used exclusively in the hospitals the increased cost of antiseptic pads would have been about $200,000.

Switzerland.

The shortage of coal in Switzerland in 1918 led to the use of peat as a source of gas. The Demolis process, by which the excessive carbon dioxide is converted into carbon monoxide in passing over wood charcoal, is used.

[3]Sherman, H. T., Suggestions for coal substitutes: Consular Dept., Nov. 25, 1918.

Canada.

Conditions in the peat-fuel industry of Canada are like those in the United States. Although Canada has many large peat deposits, coal is the staple fuel, and little has been done to produce peat fuel commercially. The following excerpt[1] shows the efforts that have been made by the Canadian Government to stimulate the production of peat-fuel:

Efforts have been made for many years to develop the peat deposits of Ontario and Quebec. Large sums of money have been spent by individuals and companies and yet there is little peat fuel produced commercially in Canada. About six years ago, however, the Government decided to make a practical investigation of peat production, and if possible to demonstrate the value of peat fuel. Representatives were sent to Russia, Germany, Holland, Denmark, and Sweden to collect data relating to peat-fuel production. When these agents returned 300 acres of peat land near Alfred, Ontario, was purchased and peat fuel was manufactured by the process which had been most economical in Europe. Approximately 2,000 short tons of peat was produced at a low cost and sold to householders and manufacturers, and it was reported by them that the peat proved to be satisfactory fuel. After this successful demonstration the Government believed that its work had been accomplished and that further development should be left to private interests. Accordingly the plant was sold, but the buyers were undercapitalized and further handicapped by the outbreak of the war, and consequently the plant ceased to operate.

In the spring of 1918, owing to the fuel shortage occasioned by the war, attention was again directed to the peat deposits and money was appropriated by the Federal Government and the provincial government of Ontario for a further demonstration of peat-fuel production. A peat committee was named, and Ernest V. Moore, of Montreal, was selected as engineer to conduct the experiments. The erection of two plants was begun, one of which was modeled after the Alfred plant mentioned and the other was a new design calculated to meet the slight defects of the former. It is understood that both machines will excavate, macerate, and spread out the peat for air drying as they move over the surface of the bog. At the close of 1918 the plants were not completed, but it is said that they will be operating at their full capacity of 6 tons each per hour during the summer of 1919.

Peat Fuel Produced in Canada, 1900-1916.

Year	Quantity (short tons).	Value.	Year	Quantity (short tons).	Value.
1900	400	$1,200	1909	60	$ 240
1901	220	600	1910	841	2,604
1902	475	1,663	1911	1,463	3,817
1903	1,100	3,300	1912	700	2,900
1904	800	2,400	1913	2 600	10,100
1905	80	260	1914	685	2,470
1906	474	1,422	1915	300	1,050
1907	50	200	1916	300	1,500
1908	60	180			

[1]Armstrong, J. E., The peat bogs of Canada: Am. Peat Soc. Jour., vol. 11, No. 2, p. 52, 1918.

Uruguay.

It is reported[1] that rights to develop peat deposits near Maldonado, Uruguay, were acquired in November, 1917, by the Sociedad Anonima Turberas Carboniferas de Maldonado, and that since then dried peat at the rate of 20,000 metric tons a month has been produced at times, although this rate of production has not been continuously maintained for more than a few days.

[1]Dawson, W. M., Commerce Repts. 47a, p. 9, 1918.

SPHAGNUM FROM BOG TO BANDAGE.

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Introduction.

Sphagnum is the only moss for which any important economic use has been reported, and the more it is studied and experimented with the more varied and extensive are found to be its uses. In a former article the writer (Hotson 1918a) endeavored to give a brief history of sphagnum as used for surgical dressings both in Europe and America, especially in its relation to the World War. A brief consideration was also given to its distribution, habitat, structure and uses together with the results of some original work on absorbency of spices best adapted to surgical work. It was further shown that it is on account of the great absorptive power due to the pressure of large, empty, perforated cells in the stem and specially in the leaf that sphagnum is so highly desirable for surgical dressings, which in many respects have proved superior to those made of absorbent cotton.

"According to Professor Porter (1917) shagnum pads surpass cotton pads in the following important particulars: (1) They absorb liquids much more rapidly, about three times as fast. (2) They take up liquids in much greater amounts; a cotton pad will absorb only five or six times its weight of water, as compared with sixteen, eighteen, and even as high as twenty-two times for a sphagnum pad. (3) They retain liquids much better, which means, of course, that the dressings need be changed less frequently. (4) They distribute the absorbed liquids more uniformly throughout their mass. (5) They are cooler and less irritating, yet at the same time fully as soft. (6) They can be produced at much less expense." (Nichols 1918a). So acceptable have these dressings proved that they have been used on practically all the allied fronts as well as in most of the base hospitals in Great

[1]Editor's Note—This work was done before the signing of the armistice and met an urgent necessity. While the urgency is gone, the call for sphagnum dressings is likely to continue in a lesser degree on their merits.

[2]Superintendent of Sphagnum Dressings for the Northwestern Division of the American Red Cross.

*Reprinted from Publication of Puget Sound Biological Station, University of Washington.

Britain, France, Italy, Egypt, and to some extent in the United States.

Of the 40 species of sphagnum found in the United States there are only four that are commonly used for surgical dressings, though other species may be used to a limited extent. In the light of our present experience, it is probable that species hitherto rejected may be utilized for this purpose. The essential qualities of desirable sphagnum are softness, flexibility, elasticity and absorbency. Other things being equal, any species that will hold at least ten times its dry weight of liquid might well be considered among those suitable for surgical dressings. But as long as plenty of material that has an absorbency of 16 to 20 can be obtained, it is obviously undesirable to use an inferior quality.

It is estimated that fully 90% of the sphagnum in the United States suitable for surgical dressings is located on the Pacific Coast, from Oregon to Alaska. Up to the time the armistice was signed the Northwestern Division was entrusted with practically all allotments for Sphagnum dressings asked for by the National Red Cross for overseas.

During the first two years of the war there was considerable opposition by British surgeons to the use of the sphagnum dressings on the ground that it was an "unnecessary makeshift." The opposition gradually disappeared, and in February 1916, they were made "official" dressings by the British War Office.

When the United States entered the war there was a similar indisposition on the part of American surgeons in France to use these dressings, a condition that one would naturally expect, as surgeons as a rule are extremely conservative, especially with the material they use in operations. Later this opposition had apparently disappeared, judging from the orders received for these dressings. At the time the armistice was signed the British were making over a million of these pads a month. The Canadian Red Cross under the direction of Dr. J. B. Porter, was working on an order of 20,000,000, and turning out between two and three hundred thousand a month; while the American Red Cross, having completed an order for half a million, had just nicely started another allotment of 1,000,000 sphagnum dressings under the direction of the writer.

Although considerable work has been done in determining the characteristics of usable moss and the species possessing them, the more difficult problems have arisen in connection with handling the moss most effectively after it has been

gathered. The object of this article is to present some of the methods and devices used in handling sphagnum from the time it is gathered until it is made into dressings.

COLLECTION OF SPHAGNUM.

The main collecting ground in Washington has been in Pacific county, while in Oregon the supply has come from the vicinity of Tillamook, Newport, Marshfield and Florence. All the moss used in the Northwestern Division has been collected by volunteer labor. "Moss drives" occurred at more or less regular intervals. These were announced through the local papers and by means of posters. In each case simple directions for collecting were printed on the back. Similar advertising was done at other centers. At first, when "moss drives" were announced, the whole town would go out in a body—men, women and children—making a picnic of it. In some instances holidays were proclaimed, all places of business closed, and the autos, delivery wagons, etc., requisitioned for the "drive." In most cases, however, these events occurred on a Sunday. As time went on and the novelty wore off, fewer responded to the call, but a goodly number of the "faithful

PLATE 31.

Carrying Sphagnum from the bog to the road.

few" were always on hand. The moss is usually collected by hand, but sometimes a fork is used as shown in plate 32.[3]

On these drives one of the hardest tasks confronted South Bend and Raymond, where they had to start at 7:30 A. M., load autos and auto trucks on barges which were taken about ten miles (16 km.) by steam tugs to Tokeland. After unloading they drove eight or ten miles to the bog, gathered the moss and returned. On such a trip they would gather from 500 to 1500 gunnysacks of moss, depending upon the size of the crowd and the accessibility of moss. All of this was volunteer work—the barges, autos, tugs, etc., all donated. The success of these drives was largely due to the energies of Captain L. L. Darling, who planned and organized them; and Mr. L. L. Bush, who located the bogs and gave the instructions in collecting.

The difficulties presented to the Red Cross workers at Tillamook were almost on a par with those just mentioned. They had to drive 20 miles (32 km.) to the bog, 10 of which were over corduroy roads. Even under these difficulties,

PLATE 32.

Collecting Sphagnum with forks in a bog near Ilwaco, Washington.

[3]The writer wishes to acknowledge his indebtedness to Prof. A. R. Sweetser for the photographs used in plates 31 and 33; to Dr. W. Haydon for those in plates 35 and 41; to the Seattle Chapter of the Red Cross for those in plates 37, 38, 39 and 44; to Miss Evelyn Gill Klahr for that in plate 42; to the engineering department of the University of Washington for the drawing in plate 43; and to the Northwestern Division of the Red Cross for making it possible to obtain many others.

sufficient moss was collected for nearly 20,000 pads. Plate 33 illustrates one Sunday's work which aggregated 2000 sacks of moss. Great credit is due to the people who live near the bogs and have cooperated in this work, many of them doing so at a real sacrifice for their sons, brothers and sweethearts at the front. It is these people who have made it possible for pads to be made in such large numbers and at comparatively little cost. It counts for little to work out the method of making an acceptable pad and to instruct women in large cities like Seattle and Portland in making them, if the raw material is not forthcoming. Never has a chapter in the Northwestern Division of the Red Cross had to stop making pads for lack of moss. They may have had to wait on the sorter or drying apparatus, but the raw material was always on hand, thanks to the cooperation of the people living near the bogs.

The following are a few of the salient points to be kept in mind while gathering sphagnum:

(1) Know exactly what you want before you begin. No collection should be undertaken until samples of the moss have been submitted to headquarters and approved. Until fairly familiar with the work, carry an approved sample of sphagnum with you and compare it frequently with the material you are collecting. If you collect the wrong moss you waste your own time and strength, the shipping expenses, and the time of the workers sorting.

(2) Gather clean moss. Collectors are often anxious to fill their sacks quickly. It is more important to fill the sacks carefully. Sphagnum badly mixed with other plants, roots and rubbish requires infinite labor in the sorting room and discourages the workers there. Aim at making a record for the quality and not for the quantity of the moss you collect.

(3) Work the moss bed as deep as possible. Sometimes suitable moss extends a foot or more below the surface. In general, whenever the plants begin to break up as a result of the first stages in decay, they must be discarded but as long as they remain intact and the stem fairly well crowded with lateral branches, they may be used, the color playing little or no part in determining the suitability.

(4) Gather the moss in double handfuls. If wet, squeeze out as much water as possible before putting in the bag but do not wring it, as that will break and injure the stem. Hasty collections often leave the moss dripping wet, and this not only adds needlessly to the weight of the sacks but increases the difficulty of drying later on.

(5) As you work your way through the bog collecting moss, take all the good materials as you go. Do not pick a little here and a little there, thus making later work in the bog difficult and unattractive. **Be thorough.**

(6) Sacks used in storing or shipping moss must first be boiled or sterilized with formaldehyde in order to prevent mildewing.

PLATE 33.

The results of one Sunday's gathering at Tillamook, Oregon; 2,000 sacks.

Storing Sphagnum.

The demands for sufficient moss to supply the daily needs where a large number of work rooms is concerned necessitates storing it for a considerable length of time, specially where the difficulties of gathering in winter are great, and the collections are entirely dependent on volunteer labor as is the case in the Northwestern Division. How best to store the moss so as to insure a constant supply is one of the difficult problems connected with sphagnum work. It is readily conceded that sphagnum keeps best in its native haunts, and if it is at all possible to obtain it during the winter directly from the bog and in sufficient quantities, that is by far the best place to keep it. This indeed may be possible to some extent in the Pacific Northwest if only small amounts are required,

but it is possible to obtain several carloads on short notice during the winter months. During the summer the bogs are comparatively dry, so that the moss may be obtained with half the energy and inconvenience that it necessitates during the rainy season. Moreover, along the Atlantic Coast and in Alaska the bogs are frozen up during the winter, making it impossible to obtain the moss under any conditions.

In considering this problem several questions presented themselves: Will the moss mildew? If so, can it be prevented? If stored wet, will it heat? If so, how may this be overcome? If wet, will it decay? These are some of the points that presented themselves at the outset. Others cropped up as time went on. In order to arrive at some solution to the problem, a series of experiments was undertaken.

(a) Moss was stored in bulk in different ways: on the floor of a well ventilated room; on the floor in the basement of large buildings poorly ventilated; and in the open exposed to the weather. When stored exposed to the weather, the moss is practically always saturated, which not only makes it unpleasant to handle but adds materially to the expense of freight if it has to be shipped. The outer portion of the pile also becomes so bleached, weathered and broken that if the moss is not entirely spoiled its usefulness is at least greatly impaired. Moreover, there is considerable opposition to sorting moss when it is excessively wet. Storing moss in a cement basement proved quite satisfactory, except that there is more tendency to mildew than where there is good ventilation. In some instances a small amount of formaldehyde was sprayed between the layers of moss as they were spread down. But this precaution was seldom necessary. The moss never heats and seldom mildews except when infected from the sacks or other things with which it comes in contact.

If the method of storing in bulk is adopted the best results are obtained by piling the moss in a heap in an unoccupied building where the floor has previously been cleaned and sprayed with a 4% solution of formaldehyde to destroy any mildew spores. It should be borne in mind that the moss will retain its moisture a long time, consequently it may seriously injure a valuable floor by warping the boards.

(b) Moss was stored in sacks as it comes from the bog. This method proved satisfactory provided the sacks were sterilized before they were used, otherwise the moss was apt to mildew. The most serious objection, however, to using sacks is the expense. When stored for a considerable time 75% to 80% of the sacks could not be used a second time on

account of partial decay due to constant moisture. Moreover, the scarcity of sacks made it almost impossible to obtain sufficient quantities for shipping purposes without using any for storage.

(c) Moss was stored in bales. The shortage of sacks suitable for shipping and the necessity for storing the moss became so acute that it was necessary to devise some method of handling it which would not require sacks. Experiments were conducted in baling the moss. Through the courtesy of the University of Washington a mechanic was put at the disposal of the writer to assist in making a baler for this purpose. Here, too, the question of whether sphagnum would heat or mildew when baled moist had to be considered; whether the moss could be baled as wet as it comes from the bog or whether it must be partially or completely dried

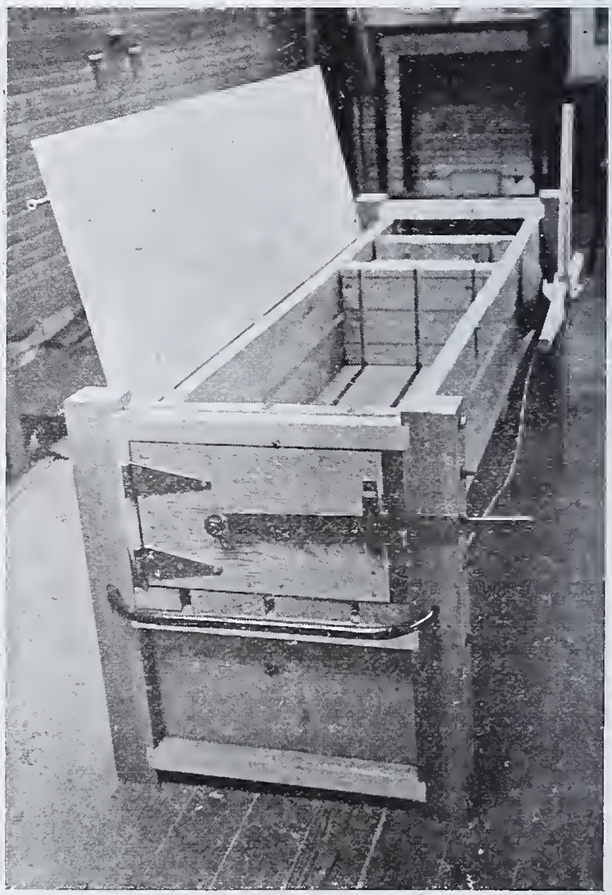


PLATE 34.

The baler used for baling moss for shipping, in the Northwestern Division of the Red Cross.

first; what effect would the pressure have on the absorbency of the moss; etc. These questions have been answered quite satisfactorily by the experiments with the baler.

Baling Sphagnum.

In making a baler it was thought best to obtain one that was inexpensive and simple, so that any carpenter might easily reproduce it. With this thought in mind, several types of balers were considered, such as those used in baling hay, paper, hops, etc. The one finally decided on was simply a modification of the principle underlying all of these.

As the accompanying photograph (plate 34) indicates, the baler is a horizontal trough 9 feet long, 17 inches wide and 12 inches deep (2.74 m. x 43.2 cm. x 30.5.). The length is sufficient to hold at one time enough moss for a single bale. The pressure for baling is obtained from a side wheel with four spokes for handles. The size of the bale is 12 x 17 inches and may be as long as is thought best. After making bales of different lengths it was decided that one 16 inches (40.6 cm.) long was the most convenient to handle. The bales are thus made 12 x 17 x 16 inches (30.5 x 43.2 x 40.6 cm.), bound by wire with three strips of ordinary lath on each end as well as the bottom and top, to keep the wire from cutting into the moss. The sides are usually left unprotected, since it is found that if the bales are piled on the side while damp they pack sufficiently to prevent the loss of any great amount of moss by handling.

Three horizontal grooves are made in piston, the inner surface of the door and on the bottom where the bales are to be made. Into these grooves the pieces of lath to protect the sides of the bale are put and held in place by brads. The trough is then filled with moss which has previously been looked over to remove any material that is useless for making pads, the lid is clamped down and the pressure applied by means of the windlass. When the moss is pressed sufficiently the piston is held in place by a dog and rachet. The lid is then raised and three additional pieces of lath are put on top of the bale in a similar position to those on the ends and bottom. The bale is wired with No. 15 double looped annealed baling wire, which is about 9 feet (2.75 m.) in length. With the size of the bale used, one of these strands will make two by cutting in the middle, leaving a loop at the end of each. The cut ends of three wires are pushed down through vertical grooves on the inner surface of the door and up through corresponding grooves in the piston, drawn tightly with strong pincers, caught in the loop and fastened on top of the bale.

The pressure is then released, the door opened and the bale removed. Clean paper is spread out and the bales are piled on it with the unprotected surface down. They should be turned from time to time.

PLATE 35.

Baling moss with an ordinary Pacific Coast paper baler.

The first bales were made early in July, some of dry moss, some with the moss slightly dampened, and others with it saturated. Several of each kind were made and stored in a well ventilated room. After two months one of each of these was opened and examined, with the most satisfactory results, especially with the moderately moist and wet bales. The dry moss, however, was broken up too much, and after further experiments it was finally abandoned as being impracticable. At the end of four months the baled, damp moss was just as fresh and sweet as when it was first baled, with no sign of heating or mildewing.

In order to safeguard against mildew in some of the bales a small amount of 4% solution of formaldehyde was sprayed when about half of the moss for the bale was in the trough. The rest of the moss was then put in and baled in the usual manner. In most cases, however, this was found to be unnecessary, and in some cases even a disadvantage, because

the moss kept moist so long that the gas did not evaporate from the center until the bales were opened, and then it was irritating to the sorter. At the writer's request, Dr. Walton Haydon, of Marshfield, Oregon, carried on similar experiments, using an ordinary Pacific Coast paper baler (plate 35), which makes a bale 24 x 18 x 18 inches (61 x 45.7 x 45.7 cm.). In these practically the same results were obtained, except that they were rather too large to handle conveniently.

The above experiments show that the principle of baling sphagnum for surgical dressings is an entirely satisfactory method of handling the moss as it comes from the bog. As has been said it never heats and seldom mildews except when infected by the container. If the bales are covered with burlap that has not been sterilized, they almost invariably mildew. Experience has shown that after the bales are made they should be kept in a well ventilated room, not piled too closely together and never covered with anything that will likely contaminate them. The practicability of baling sphagnum for surgical dressings is also in accord with the experience of Dr. Porter in dealing with the Nova Scotia moss.

Sorting Sphagnum.

There must at all times be a close relation between the process of gathering moss and sorting it. Experience has shown that carelessness on the part of the collector may greatly reduce the efficiency of the sorter, frequently rendering otherwise useful moss absolutely worthless. The amount of moss sorted is thus proportional to the care of the gatherer, and yet it is readily seen that with the difficulties confronting the collector, too much time cannot be spent on that end of the work, as there are a hundred persons available for sorting where there is one for collecting. There is a happy mean to which we should strive in order to obtain the greatest results with the least labor. Picking over or sorting the moss is usually one of the tedious phases of making sphagnum dressings. The sorting may be done either in some central place or at several centers. Good results have been obtained by distributing the moss to women's clubs, who sort and return it to the place where it is dried. In some places a great deal of assistance has been rendered by high school teachers and students. In such cases a small portion of the regular school time may be allotted to this work, or if there is objection to that, volunteers may be asked to remain half an hour or even an hour after the school is dismissed.

The following are a few suggestions for the sorter to keep in mind:

1. Moss to be sorted should be spread out several hours in advance, preferably on the previous day. If it is in a damp condition the large lumps may be slightly shaken apart and separated; but if dry and packed, as is more likely to be the case, it should be sprinkled lightly with water and an oilcloth thrown over it for several hours, or over night if possible.

2. In cleaning the moss it is not necessary to remove every particle of foreign matter such as tiny bits of leaves or grass, but, of course, all the larger leaves, all bits of stick, any sharp pine needles, stiff grass, etc., must be removed. As the moss is spread out in the drying frames it should be looked over a second time as a matter of precaution.

3. After the moss is sorted, do not leave it in sacks for any length of time but spread it out as soon as possible. If it is allowed to dry in the bag it frequently forms a hard lump which when pulled apart breaks up the moss.

4. When dry, handle the moss just as little as possible, as in handling it the small leaves are broken off. It is these leaves that do the work of absorption, hence the more that are lost the less efficient the moss. Never sort dry moss. If, inadvertently, it becomes too dry, moisten it.

Drying Sphagnum.

The fact that sphagnum absorbs such a large amount of water and holds it with such tenacity makes the process of drying one of the most difficult steps in the preparation of the moss for dressings and one that has required a great deal of careful thought and experimentation. This is particularly true along the Pacific Coast during the wet season when the atmosphere approaches saturation for months at a time.

Experiments have shown that artifically dried sphagnum is harsher and far more brittle than moss that is dried in the open air under ordinary conditions. This is due to excessive drying in which not only the water contained in the reservoir cells is removed but also that in the green cells and the walls of the plant. It is the removal of this excessive amount of moisture, depriving the plant of its elasticity, that makes it brittle and harsh. In ordinary air-dried moss a portion of this moisture is retained by the plant for a longer time, and if removed at all it is so gradually that the walls are left flexible. Dr. Porter suggests that "it is probable that the

PLATE 36.

A drying rack used in the work rooms at the University of Washington. A working drawing is shown in plate 43, Fig. 1.

controlling factor is the relative humidity of the circulating air rather than the rate at which the sphagnum is dried. For example, I see no difference between moss dried in summer by placing it near a stove and that dried in trays in an ordinary Montreal workroom in winter. In the first place, the temperature is probably over 100° F., whereas, in the second, it is only about 65° F., but in each case the relative humidity is very low, probably ten or fifteen per cent. The moss is thus almost completely desiccated. We have gone so far as to recommend that in winter drying rooms should be kept just as cold as possible for the work of the people. We have even discussed the advisability of humidifying them somewhat after the method employed in certain branches of cotton spinning."[4] There seems to be no objection to using

[4]From a communication to the American Red Cross.

artificial heat, or any other means of drying, provided the drying is not carried too far. For instance, it would be perfectly in accord with the facts thus far known, to use artificial heat, say up to 90° or 100° F. at first, and then finish the drying without artificial heat.

In considering any apparatus for drying the greatest precaution should be taken not to handle the dry moss any more than is absolutely necessary, and any contrivance that stirs or shakes it while drying should be avoided as far as possible. Rough handling tends to break off the minute branches and leaves which are the parts of the plant that make it valuable for surgical work.

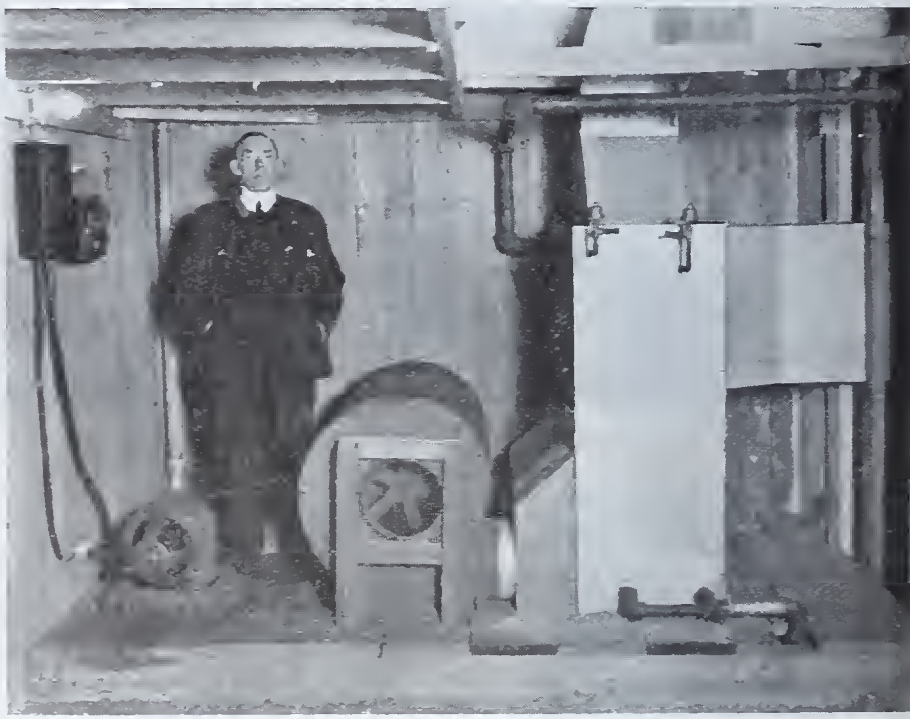


PLATE 37.

The blower with 2 H.P. motor that supplies the air for drying the moss in the trays in plate 38. This is installed in the Seattle Chapter of the Red Cross.

A convenient means of drying moss on a small scale suitable for most of the smaller Chapters is a rack such as is used at the work rooms at the University of Washington (plate 36). Each shelf is four inches deep (10 cm.), the bottom covered with chicken wire, which, in turn, is covered with unbleached muslin. In removing the dried moss it has

been found most convenient to draw out the muslin with the moss on it, one person holding each end and emptying all of it at once, thus avoiding much handling.

The most elaborate plan for drying sphagnum in the Northwestern Division is that installed in Seattle and is illustrated in plates 37, 38 and 39. This was planned and constructed by Mr. Harding Gow, who is a full-time volunteer at the Seattle Chapter. The drier is located on a balcony six and a half feet (2 m.) wide and about seventy feet (20.3 m.) long, above the main workroom. The moss is placed in trays 30 x 32 inches and 1⅝ inches deep (76.2 x 81.3 x 3.13 cm.). The tray have galvanized fly screen bottoms and are arranged in racks of which there are 22 in all, each rack holding 18 trays, giving a total of 396. The racks (plate 38) are placed at the outside edge of the balcony, leaving a space of 4 feet (1.2 m.) between the trays and the wall. The balcony floor is 14 feet (4.27 m.) below the ceiling. This space is divided into two stories by a light floor, having nine tiers of trays on each floor. The air is heated by two stacks of six tiers, Vento radiation, 9¾ x 60 inches (24.8 cm. x 18.3 m.) enclosed in a sheet iron case. The air is forced through this case by a double 11-inch (27.9 cm.) blower driven by a two horse-power motor. It is delivered from the case by two outlets 12 x 24 inches (30.5 x 61 cm.) in cross section, which are located at the end of the balcony near the back wall and also as near the floors of the passages as the radiators will allow, as experiments have shown that the heated air will travel farther along the passage when the inlet is near the floor. The opposite end of the passage is closed by a light door, so that all the heated air delivered into the passage is forced through the trays.

The blower (plate 37) runs at 860 revolutions per minute, delivering between 5000 and 6000 cubic feet (424-510 cbm.) of air. The maximum temperature of the air actually in contact with moss is about 90° F. The trays when filled level full will dry 24 hours. Each tray has a capacity of ½ pound (227 g.) of dry Sphagnum palustre, or ¾ pound (340 g.) of dry Sphagnum imbricatum, the two species commonly used. If run at its full capacity, therefore, this drier will insure 200 to 300 pounds (91 to 136 kg.) of dry moss per day, which should make a minimum of 2100 dressings 12 x 24 inches (30.5 x 61 cm.) or 6300 dressings 8 x 12 inches (20.3 x 30.5 cm.).

The moss, after it has been sorted is hoisted in large clothes baskets to the balcony and emptied into carts, each of which holds three baskets. The carts are wheeled down the

passage and the trays filled. The dry moss is stored temporarily in a large bin extending from near the main floor up to the balcony (plate 39). As it is needed it is drawn off by means of a chute that leads to the main floor.

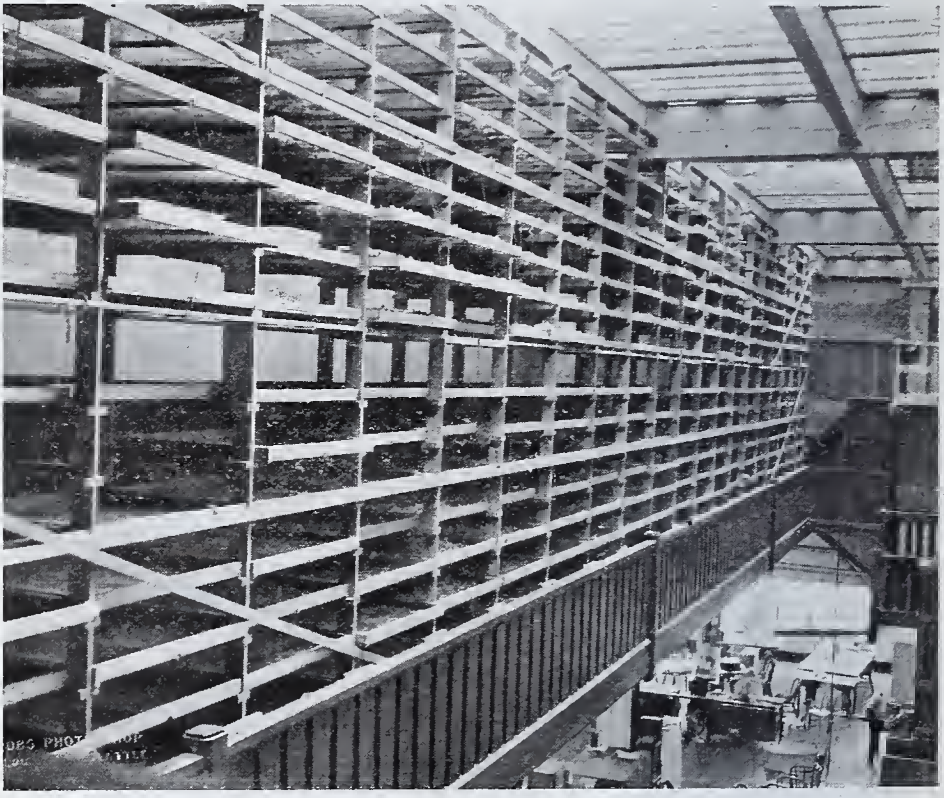


PLATE 38.

Arrangement of the trays for drying moss in the Seattle Chapter.

A third type of drier has been suggested by Mr. L. L. Bush, Divisional Field Representative in Pacific County. The device consists of a box or tank which is air tight, except that it is open at the top. The air-tight feature is such that the box will stand a slight pressure from the inside without leaking save as the air escapes above. It is constructed of ¾-inch (1.9 cm.) lumber lined on the inside with stiff paper and sealed at the joints with some quickly drying material. About a foot (30.5 cm.) from the bottom is a false floor consisting of fine chicken wire similar to that used above. Through an opening near the bottom a shaft connects the air chamber with a small fan and motor. The moss is laid evenly on the screen floor to a suitable depth and packed well against the sides so that the air has no special channels for passage but is distributed

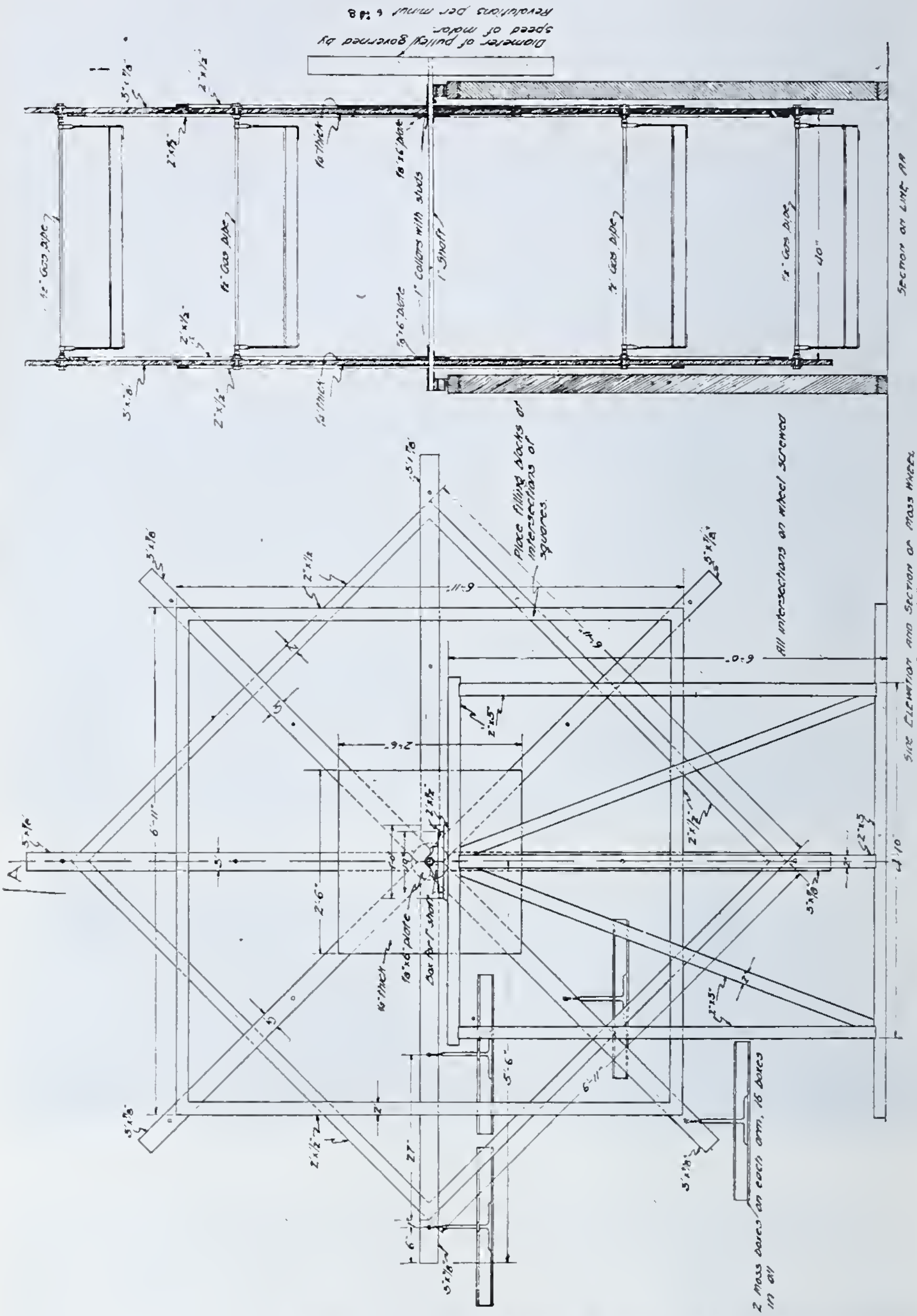
PLATE 39.

A portion of the trays shown in plate 38 and the bins for storing the moss; also the chute for carrying the moss to the ground floor.

equally through the moss. The rate of drying depends upon the amount of circulation. A large and strong inflow of slightly warmed air (about 90° F.) will produce fairly rapid drying.

The value of this method lies in the forced circulation through the moss.

A device (plate 40) used for drying moss has been designed by Mrs. Austin R. Baldwin of the New York County



Side elevation and section of the "Ferris" wheel used in the New York County Chapter of the Red Cross. Designed by Mrs. Austin R. Baldwin.

Chapter of the American Red Cross. This is constructed on the plan of a Ferris wheel which is 11 feet (3.35 m.) high with eight pairs of arms, each pair supporting two trays of moss, making sixteen in all. Each tray is 33 x 22½ x 2½ inches (833.8 x 57.2 x 6.4) with ¼-inch (6.3 mm.) wire screen for the bottom and top. The trays are filled with moss of about the same degree of dampness, and the wheel is kept in motion by a one horse-power electric motor.

In connection with this drying apparatus some valuable experiments were undertaken to ascertain if humidity is a factor to be considered in drying moss artificially.[5] To this end an attempt was made to make the atmosphere of the drying room similar to that which might be called a good drying day, with special care as to the relation of temperature and humidity. Artificial heat was furnished by a gas heater. The temperature was regulated by means of gas burner rings of different diameters, three in all, controlled by stop cocks as in a gas range. Air was forced through the heater by an electrically driven motor (½ H. P.) making 2700 revolutions per minute. The temperature maintained in the drying room was made to conform to the percentage of relative humidity desired. In any event, the temperature was not allowed to rise about 105° F., as a higher temperature seemed to be deleterious to the moss. On days of low humidity moisture was provided for by live steam, by a pan of water on the heated pipe from the heater, or by passing intake air over water. Wet and dry bulb thermometers were used to determine the condition of the room air and outside air.

For the first one or two hours of drying, depending on the moisture content of the moss, the relative humidity, was held between 50% and 60% to avoid too rapid drying. When the sphagnum appeared to be about half dry, the percentage of relative humidity was lowered, and the drying was finished with a relative humidity of about 30%. If the moss was half dried in the racks before being put in the wheel the relative humidity was at once lowered to about 30%.

The wheel, when originally installed, made six revolutions per minute. This was increased to eight revolutions per minute, increasing the mean velocity of the outer trays from 188.5 feet (57.5 m.) per minute to 251 feet (76.5 m.) per minute, the mean velocity of the inner trays from 94 feet (27.7 m.) per minute to 125.6 feet (38.3 m.) per minute, with beneficial results.

[5]The writer is indebted to Mrs. Austin R. Baldwin for the facts concerning these experiments.

The moss in the outer trays dries more rapidly than that in the inner trays, furthermore, the moss at the edges of the outer trays exposed to a larger volume of air, dries more rapidly than that at the edges exposed to a smaller volume. It was found advisable not only to exchange the inner trays with the outer ones during the process of drying, but also to turn the trays half way round to get uniformity in drying.

Sometimes it was necessary to run the wheel all night in order to obtain sufficient moss, but in such cases the heater and blower were shut off at 10 p. m. It requires from 10 to 12 hours for all the moss on the wheel to become dry, while moss drying naturally in trays in an adjoining room would require 48 to 72 hours, according to the weather. The reasons for this were: first, the higher temperature of the drying room, which at 10 p. m. had risen to 95° to 100° F., but fell to within two or three degrees of the temperature of the adjoining room by morning; and second, the motion of the moss in the trays on the wheel through the air of the drying room. Air circulation seemed to be an important factor. When these conditions became apparent three electric fans were installed. These also accelerated the changing of the air in the drying room between drying periods.

Absorbency tests of five pads made from naturally dried moss and a similar number from artificially dried moss show that the latter absorbs within three per cent as much water by capillarity as the former. Although perhaps this investigation has not been carried on long enough to come to a definite conclusion yet these preliminary experiments suggest that moss artificially dried under proper relations of temperature and humidity might be of great value in making surgical dressings.

As has been stated above, the American Indians used sphagnum quite commonly as dressing. Their methods (plate 41) was to throw the moss upon bushes or string it along poles. This is one of the best and most effective ways of drying if the weather is suitable, but it is extremely wasteful. One of the methods used by Dr. Haydon for drying in the field is fashioned after the Indian method, and consists of a framework with crossbars on which the long strands of Sphagnum palustre are strung. When dried the moss is spread out in the center of a sheet 6 x 9 feet (1.8 by 2.7 m.), the sides folded over the moss and then rolled up from the end and roped. Another method of drying, used by Dr. Haydon consists of a framework made of two by two inch (5.5 cm.) scantling with ordinary lath one inch (2.54 cm.) apart as a bottom, on which

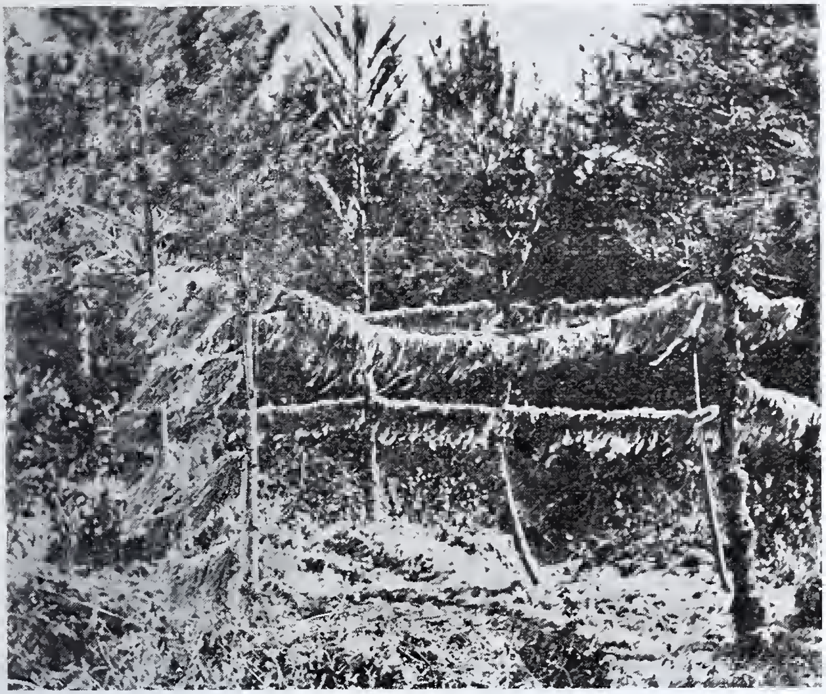


PLATE 41.

The Indian method of drying Sphagnum.

PLATE 42.

A method used in Nova Scotia for drying Sphagnum. It consists of a framework with galvanized wire screen for bottom, and muslin or cheese cloth around the edges to prevent the wind from blowing the moss away.

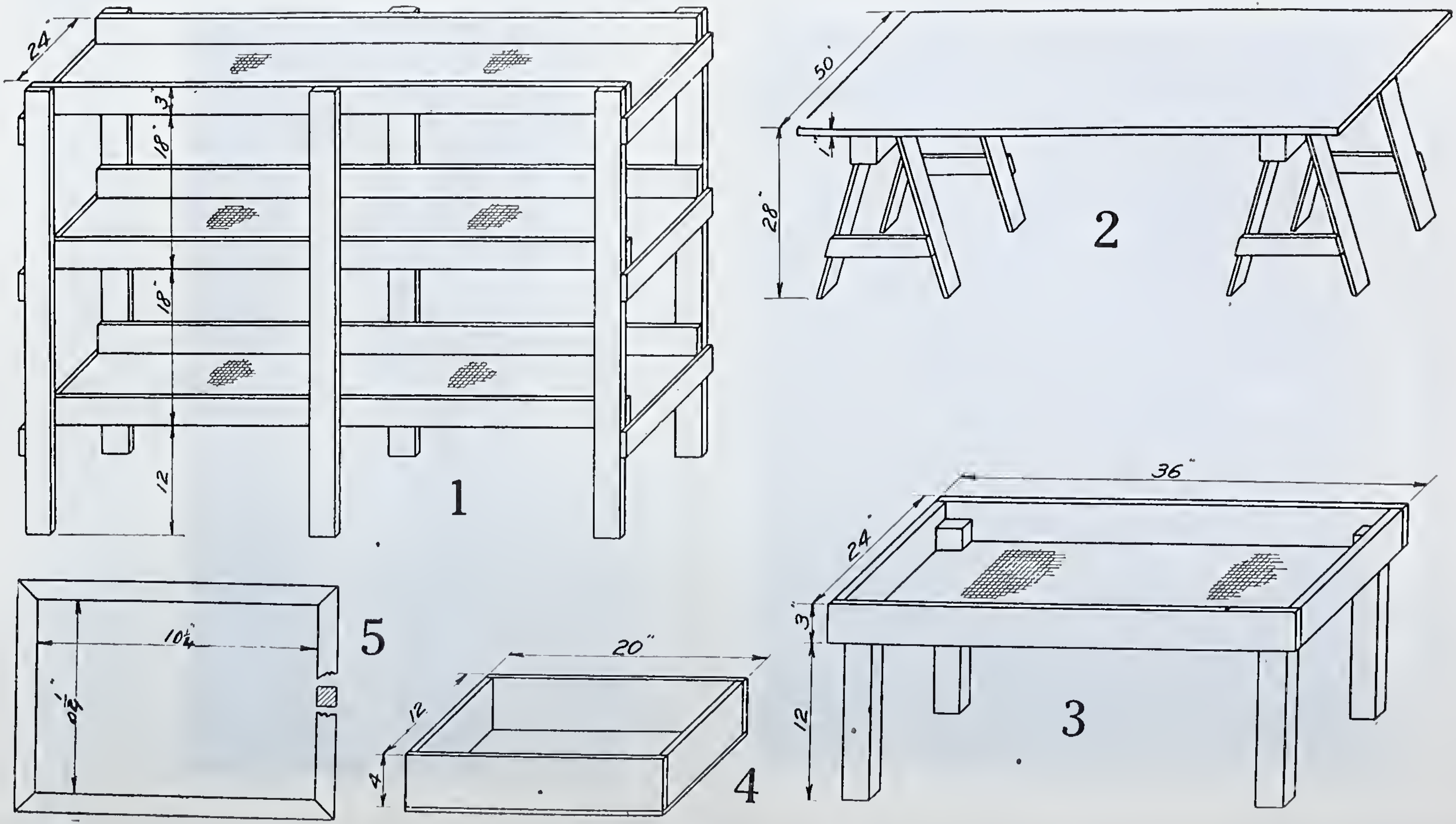


PLATE 43.

PLATE 43—Page 198.

Part of the equipment used at the University Auxiliary of the Red Cross, Seattle.

Fig. 1. A drying rack; length made to suit the room; bottom of galvanized chicken wire with small mesh; made of dressed ¾ x 3 inch (1.9 x 7.6 c. m.) lumber. Photograph shown in plate 36.

Fig. 2. A convenient table for a work room either for making pads or sorting moss; length of table to suit size of room; may be made of common lumber 1 inch (2.5 cm.) thick planed on one side; top and edges protected with building paper covered with 54-inch (1.34 m.) pebble oilcloth.

Fig. 3. A drying tray; made so that several can be stacked on one another; bottom similar to that in Fig. 1.

Fig. 4. A tray for dry moss; for holding material while pads are being made; composed of ½-inch (1.3 cm.) dressed lumber.

Fig. 5. A moss frame for an 8 x 12 inch (20.3 x 30.5 cm.) pad. Used as a guide in determining the appropriate amount of moss for the pad.

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the moss is spread. The moss is covered by a piece of fish net to prevent it from being blown off the rack.

In Nova Scotia sphagnum is sometimes dried in the field on racks (plate 42,) the sides of which are closed in by strips of unbleached muslin or cotton to avoid the loss of moss by the

PLATE 44.
Passing the completed pads through a clothes wringer run by electricity.

wind, while the bottom is made of galvanized chicken wire similar to that used in indoor drying rack.

After the moss has been dried, no matter in what way, it is stored loosely in bins, if the quantity is large, but in small Chapters pasteboard cartons have been found convenient and usually sufficient for storing the excess of dry moss.

Equipment of A Sphagnum Workroom.

The equipment for making sphagnum surgical dressings need not necessarily be elaborate. The ideal condition is to have three separate rooms conveniently located with respect to each other, one for sorting, one for drying the moss after it has been sorted and one for making the pads. The room space might be reduced by having certain days for sorting and others for making the pads so that these two processes might be carried on in the same room. In such a case the same tables, a convenient type of which is shown in plate 43, Fig. 2, could be used for both.

In the drying room one of the methods of drying described above should be installed. The racks (plates 36; and 43, Fig.

PLATE 45.

A class of University of Washington women working on the first 50,000 sphagnum pads.

I) have proved the most satisfactory for small Chapters where allotments do not run more than 10,000 pads a month. The drying trays (plate 43, Fig. 3) are convenient where floor space is a consideration. In the room for making the pads, besides the ordinary tables and cutting table to be described shortly, there should be the following: (1) a sufficient number of moss frames (plate 43, Fig. 5) of appropriate size for gauging the amount of moss ; (2) dry moss trays (plate 43, Fig. 4) for holding moss while pads are being made; (3) spring clothes pins for holding the zorbik envelope in place; (4) a few yard sticks; (5) a polished foot ruler (3 dm.) for each worker; (6) large clothes basket for carrying pads and moss; (7) a convenient place for storing the sorted dry moss; (8) a clothes wringer (plate 44).

Making Sphagnum Pads

When the moss is perfectly dry it is ready to be made into dressings which are composed of gauze, a thin sheet of wood pulp paper (known as zorbik or Scot tissue), non-absorbent cotton and Sphagnum. Plate 45 is a photograph of a class of University of Washington girls working on the first 50,000 sphagnum pads made by the American Red Cross for overseas.

In cutting the gauze care should be taken so as not to cut it on the bias. In order to avoid this many smaller Chapters draw the thread and cut by hand. This, however, is slow and tedious when pads are called for by the hundred thousand.

(a) A Gauze Cutting Table

If a considerable quantity of cutting is required, either of gauze or zorbik,[6] it is best to have a special table which should be marked with parallel longitudinal lines, the two outside ones spaced the width of the gauze; while between these should be lines parallel to them along which the gauze is to be cut. Cross lines are drawn where the cross cuts are to be made. The two end guides are placed half the space from two selected cross lines, as the gauze is doubled at the ends. They are usually about 8 feet (2.44 m.) apart and fastened to the table with wing nuts. The straight edges, which are each one-eighth of an inch (3.2 mm.) thick, three inches (7.62 cm.) wide and 3½ feet (1.1 m.) long, holds the folds up to the end guides.

To hold the gauze along the sides No. 1 harness needles with the temper drawn, or pieces of knitting needles about three inches (7.6 cm.) long, may be used. These needles are

[6]Zorbik or Scot tissue is a very thin wood-pulp paper used to envelop the sphagnum and prevent it from sifting out.

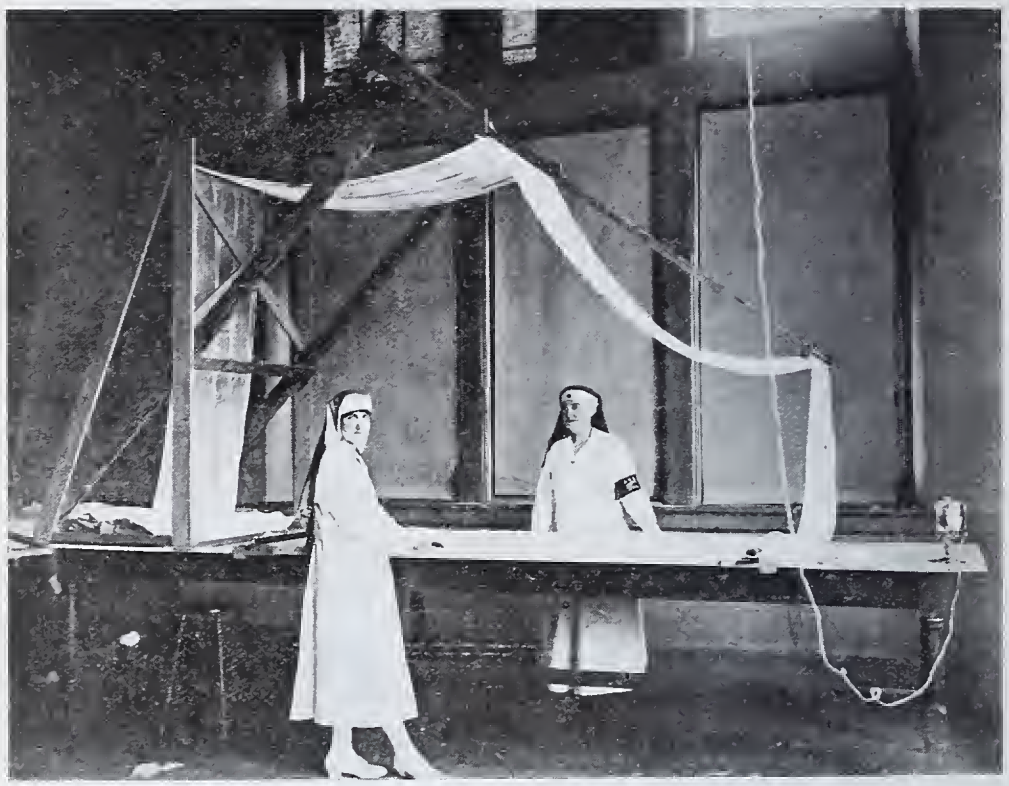

PLATE 46.

A gauze-cutting table with an overhead spreading and folding device.

forced into the table along the outside lines three and one-thirty-second inches. (7.86 cm.) from the cross lines, so that when one of the straight edges is against them, a pencil will mark along the edge directly over the cross line on the table. When cutting gauze the bolt is laid on the end of the table beyond where the folding is to take place. A layer of gauze is stretched out on the table and the edges kept straight by putting the selvage over the needles. The straight edge is slipped between the layers, thus holding the folds up to the guide. One of the weights is placed on the straight edge to keep it from slipping. Each of these weights is made of two strips of wood 1/8 inch (3.2 mm.) thick, 1¾ inches (4.4 cm.) wide, and 2 feet 2 inches (81.3 cm.) long; with lead strips between them 1¼ inches (3.2 cm.) wide and weighing 6 or 8 pounds (2.7 — 3.6 kg.). The whole is covered with cloth.

After the weight is placed on the straight edge the gauze is stretched back to the opposite end and another straight edge and weight used in a similar way there. This process

is continued back and forward, each time securing the selvage over the needles. When the four straight edges have been used, the lower one is drawn out and used again. When a bolt has thus been stretched out on the table, light lines are drawn where the cuts are to be made. This cutting may be done with an electric cutter or by hand.

(b) A Spreading and Folding Device.

A device (plate 46) for spreading and folding gauze has been designed by Mr. W. H. Durham, superintendent of buildings and grounds at the University of Washington, where it is installed. It has proved very convenient in avoiding confusion and delay that ofter arise in spreading the gauze by hand. This device consists of a rather inexpensive framework that is fastened to one end of the cutting table with a swinging arm to carry the gauze back and forth. The bolt of gauze is laid between the upright frames at one end of the table. The loose end of the gauze is drawn over the glass tube directly above, then over the other upper glass tube and down between the two glass tubes at the lower end of the swinging arms. These glass tubes, it should be remembered, have a ¼-inch (6.3 mm.) iron bolt running through them for support.

The gauze is then spread on the table as already indicated. As the arm is swung back and forward the gauze is spread and is always kept up out of the way. An extra board put on the upper end of the swinging arm is just sufficient to balance the long arm so that it remains wherever it is placed, and can easily be pushed up out of the way when not in actual use. With this device a bolt of gauze containing 100 yards (91.4 m.) can easily be spread and cut in half an hour by two people.

(c) General Directions for Making Sphagnum Dressings

In making a sphagnum dressing a piece of zorbik or Scot tissue of appropriate size is placed on the table and on it a wooden frame corresponding to the particular size to be made. The frame used for the 8 x 12 inch (20.2 x 30.5 cm.) pad is 6¼ x 10¼ x ½ inches (15.9 x 26 x 2.3 cm.); for the 12 x 24 inch (30.5 x 61 cm.) pad is 10¼ x 22 x ¾ inches (26 x 55.9 x 1.9 cm.) and the one for the 14 x 20 inch (35.6 x 50.8 cm.) pad is 12 x 18 x¾ inches (30.5 x 45.7 x 1.9 cm.) Some prefer using a piece of pink cardboard the same size as the inner measurements of the frame, placing it under the gauze to indicate the limits of the moss, but the frame is generally found more satisfactory. It is immaterial which device is used so

long as the results are obtained. The frame is filled evenly with moss but not packed. Over this a thin layer of cotton is placed and the frame removed. The margins of the zorbik are then folded over the cotton sphagnum. It is usually convenient to use spring clothes-pins to hold the ends in place, although this is not absolutely necessary. In order to keep the outside covering free from particles of moss it is best to remove this incomplete pad to another table where there is no moss. Here it may be finished by the same worker or by another. A piece of gauze of appropriate size is spread out on the table and the incomplete pad on the center of it, with the non-absorbent cotton up. A thicker layer of cotton is then put over the pad. extending about ½-inch (1.3 cm.) beyond the edges. The gauze is folded over the pad so that the long fold is on the back, that is, on the side next the non-absorbent cotton. The open ends are folded in "muff-wise," first folding the under side up over the zorbik envelope, then folding the upper side to correspond and adjusting the "muff-end" carefully. The pad is patted lightly to make sure the sphagnum is evenly distributed throughout, and then passed through a clothes-wringer (plate 44). The object of putting the pad through the wringer is partly to reduce its thickness, thus saving shipping space; and partly to press the moss into the thin layer of cotton and zorbik thus preventing it from shifting when handled. This is extremely important specially in large pads. The zorbik which envelopes the sphagnum and the thin layer of cotton keeps the moss from sifting out, the thicker layer of non-absorbent cotton on the back prevents the discharge from soaking through the bandages, and the gauze on the outside holds everything in place, exposing a soft absorbent surface to the wound. A photograph showing the steps in making a standard sphagnum pad 8 x 12 inches (20.3 x 30.5 cm.) is shown in plate 47.

(d) Directions for Making Dressings for Overseas.

The following directions give in detail the method of making certain sphagnum pads. These directions are based on the original ones received from Dr. John A. Hartwell, director of surgical dressings for the National Red Cross. Even after nearly a year of experimentation with them they are published with some degree of hesitation. They are given in detail mainly in order to preserve a record of them. For overseas three sizes of pads are made: 8 x 12 inches (20.3 x 30.5 cm.), 12 x 24 inches (30.5 x 61 cm.), and 14 x 20 inches (35.6 x 50.8 cm.) The specific directions are given below for each of these:

PLATE 47.

The successive steps in the making of a sphagnum pad. (1) Frame on zorbik. (2) Moss in frame. (3) A thin film of non-absorbent cotton on moss. (4) Frame removed; zorbik folded from left. (5) Zorbik folded from right and the near end; spring clothes pins holding zorbik in place at the near end. (6) Far end of zorbik folded and held with spring clothes pins. (7) Zorbik envelope with moss side next the gauze. (8) Clothes pins removed. (9) Gauze folded in from left. (10) Gauze folded in from right. (11) Pad turned over. 12. Near end muffed (13) Both ends muffed and patted even. (14) Ten pads tied for packing.

8 x 12 inch (20.3 x 30.5 cm.) pads.

(A)

1. Cut the gauze 20 x 18 inches (50.8 x 45.7 cm.).
2. Cut zorbik 15 x 13½ inches (34.3 x 38.1 cm.) and stretch to 16 inches (40.6 cm.) Cut twice as many pieces 12 x 7 2/3 inches (30.5 x 19.5 cm.) and stretch to 9 inches 22.9 cm.).
3. Cut non-absorbent cotton 8 x 12 inches (20.3 x 30.5 cm.). Make thick enough to weigh ½ ounce (14.2 g.). This weight will vary a little as cotton varies in quality and uniformity.

(B)

1. Place one large sheet of zorbik with 15-inch (38.1 cm.) side parallel to edge of table. Place in center of this two face-pieces with 9-inch (22.9 cm.) side parallel to edge of table. If the zorbik is of poor quality two large sheets may be necessary.

2. Place wooden frame in center of zorbik with 6¼-inch (15.9 cm.) side parallel to edge of table. Frame should measure 6¼ x 10¼ x ½ inches (15.9 x 26.7 x 1.27 cm.), inside measurements. Place sphagnum in frame filling it evenly but not packed.
3. Cover sphagnum with thin layer of non-absorbent cotton. Remove frame.
4. Fold zorbik from sides over sphagnum and cotton, then fold ends over pad. (When pressed down the zorbik envelope should now measure 6½ x 10½ inches, or 16.5 x 26.7 cm.)
5. Pass zorbik envelope to separate table for gauze.

(C)

1. Place gauze on table with selvage at top.
2. Place zorbik envelope in center of gauze with 6½-inch (16.5 cm.) side paralled to edge of table.
3. Place the backing of non-absorbent cotton on pad, with a margin of cotton extending beyond the zorbik envelope on all sides.
4. Fold gauze from left to right over pad; turn in and cut edge at right about 1½ inches (3.81 cm.) and then fold from right to left over pad. Turn pad over and muff ends on face of pad, i. e. on paper side of pad.
5. At this point, if gauze has been wrapped snugly, the pad should measure 7¾ x 11¾ inches (19.5 x 29.8 cm.) or a little less; and if all measurements have been carefully followed, there should be a margin of non-absorbent cotton on all sides of zorbik envelope, varying from a little less to a little more than ½ inch (1.27 cm.) in width, depending upon the firmness of the zorbik envelope and the stretchiness of the zorbik.
6. Pass for careful inspection, then sew with medium sized stitches along both ends and the back fold.
7. Pass through wringer. Pad will now measure 8 x 12 inches (20.3 x 30.5 cm.) and weigh from 1¼ to 1¾ oz. (35.4 to 49.6 g.). Weight must be kept within these limits.
8. Tie in packages of ten with the face side up, except the top one which should be face down; thus a cotton side is exposed on top and bottom of the package.
9. Label: "10 Sphagnum Absorbent Pads 8 x 12 inches (20.3 x 30.5 cm.).

N. B. Cotton side does not go next to the wound."

12 x 24 inch (30.5 x 61 cm.) pads.

(A)

1. Cut the gauze 30 x 36 inches (76.2 x 91.4 cm.).
2. Cut zorbik 26 x 27 inches (66 x 68.6 cm.) and stretch to 29 inches (71.1 cm.) with the 26-inch (66 cm.) edge parallel with the grain of the zorbik. If the zorbik does not come in the large sheets, cut 26 inches (66 cm.) by width. Also cut twice as many sheets 26 x 13 inches (66 x 33 cm.).
3. Cut cotton 12 x 24 inches (30.5 x 61 cm.) Make thick enough to weigh 1½ oz. (42.5 g.) if a good uniform cotton is used, or 2 oz. (56.7 g.) if using Burton-Dixie cotton.

(B)

1. Place one large sheet of zorbik with the 26-inch (66 cm.) side parallel to the edge of the table, and in the center of this two face-pieces slightly larger than the wooden frame, with the grain running at right angles to that of the large piece. If the zorbik is of poor quality two larger sheets may be necessary.
2. Place wooden frame in center of zorbik. (Frame should be 10½ x 22 x ¾ inches, or 26.7 x 55.9 x 1.9 cm., inside measurements.) Place sphagnum in frame filling it evenly but not packed.
3. Cover sphagnum with a thin film of non-absorbent cotton. Remove frame.
4. Fold zorbik from sides to center over the sphagnum and cotton; then fold ends over pad.
5. Pass the zorbik envelope to a separate table for gauze.

(C)

1. Place gauze on the table with selvage at the top and bottom.
2. Place the envelope in the center of the gauze with 10½-inch (26.7 cm.) side parallel to the selvage of gauze.
3. Place a backing of non-absorbent cotton on the pad, with a margin of non-absorbent cotton extending well beyond the zorbik envelope on all sides.
4. Fold the gauze from left to center, turn in cut edge at right and fold from right to center. Muff ends of gauze on face of pad, i. e., on paper side of pad.
5. Pass through wringer.

6. Tie in packages of five with the face side up, except the top one which should be face down; thus a cotton side is exposed on top and bottom of the package.
7. Label: "5 Sphagnum Absorbent Pads, 12 x 24 inches (30.5 x 61 cm.).

   N. B. Cotton side does **not** go next to the wound."

14 x 20 inch (35.6 x 50.8 cm.) pads.

(A)

1. Cut the gauze 24 x 36 inches (61 x 91.4 cm.).
2. Cut zorbik 32 x 23 inches (81.3 x 58.4 cm.) and stretch to 25 inches (63.5 cm.). Cut twice as many face pieces 21 x 10 4/5 inches (53.3 x 27.4 cm.) and stretch to 15 inches (3.81 cm.)..
3. Cut non-absorbent cotton 14 x 20 inches (35.6 x 50.8 cm.) Make thick enough to weigh 1½ oz. (42.5 g.) if using a good uniform cotton, or 2 oz. (56.7 g.) if using Burton Dixie cotton.

(B)

1. Place one large sheet of zorbik with 32-inch (81.3 cm.) side parallel to edge of table. Place two face-pieces in center with 15-inch (38.3 cm.) side parallel to edge of table. If the zorbik is of poor quality two large sheets may be necessary.
2. Place wooden frame in center of zorbik with 12-inch (30.5 cm.) side parallel to edge of table. (Frame should be made 12 x 18 x ¾ inches or 30.5 x 45.7 x 1.9 cm., inside measurements.) Place sphagnum in frame filling it evenly but not packed.
3. Cover sphagnum with a thin layer of non-absorbent cotton. Remove frame.
4. Fold zorbik from sides to center over sphagnum and cotton; then fold ends over pad. (When pressed down the zorbik envelope should measure approximately 12¼ x 18¼ inches, or 30.9 x 46.3 cm.).
5. Pass zorbik envelope to separate table for gauze.

(C)

1. Place gauze on table with selvage right and left.
2. Place zorbik envelope in center of gauze with 12¼-inch (30.9 cm.) edge parallel to edge of table.
3. Place the backing of non-absorbent cotton on the pad with a margin of cotton extending well beyond the zorbik envelope on all sides.

4. Fold gauze from left to right over pad; then from right to left over pad. Turn the pad face upward and muff ends of gauze on face of pad, i. e., on paper side of pad.
5. At this point, if gauze has been wrapped snugly, the pad should measure 13¾ x 19¾ inches (35 x 50.1 cm.) or a little less. And if all measurements have been carefully followed there should be a margin of non-absorbent cotton on all sides of the zorbik envelope, varying from scant ¼ to ¾ inch (.6 x 1.9 cm.) in width depending upon the firmness of the tissue envelope and the stretchiness of the zorbik.
6. Pass for careful inspection, then sew both ends and along the back with medium sized stitches.
7. Pass through wringer. Pad will now measure 14 x 20 inches (35.6 x 50.8 cm.) and weigh 4 to 4½ oz. (113 — 128 g.). Weight must be kept within these limits.
8. Tie in packages of 5 with the face side up, except the top one, which should be face down; thus a cotton side is exposed on top and bottom of the package.
9. Label: "5 sphagnum Absorbent Pads 14 x 20 inches (or 35.6 x 50.8 cm.). N. B. Cotton side does **not** go next to wound."

(e) Directions for making dressings for base hospitals in U. S.

Base hospitals in this country seldom, if ever, need dressings as large as those just described. Consequently the sizes of sphagnum pads for their use have been greatly reduced to meet particular needs. The commonest ones called for are 7 x 7, 4 x 6, 4 x 4, and 2 x 3 inches (17.8 x 17.8, 10.2 x 15.2, 10.2 x 10,2, 5.08 x 7.6 cm.).

7 x 7 inch (17.8 x 17.8 cm.) pads.

(A)

1. Cut the gauze 17 x 12 inches (43.2 x 30.5 cm.).
2. Cut zorbik 15 x 10 inches (38.1 x 25.4 cm.).
3. Cut non-absorbent cotton 7 x 7 inches (17.8 x 17.8 cm.).

(B)

1. Place one or two sheets of zorbik, according to the quality, on the table with the 15-inch (38.1 cm.) side parallel to edge of table.

2. Cover area of 6 x 6 inches (15.2 x 15.2 cm.) in center of zorbik with thin layer of sphagnum. A piece of stiff colored paper 6 x 6 inches (15.2 x 15.2 cm.) placed under zorbik is useful as a guide in making this pad.
3. Fold zorbik from sides over sphagnum. Then fold ends over pad.
4. Pass zorbik envelope to separate table for gauze.

(C)

1. Place gauze on table with selvage at top.
2. Place zorbik envelope in center of gauze with end parallel to edge of table.
3. Place the backing of non-absorbent cotton on pad with a margin of cotton extending well beyond the zorbik envelope on all sides.
4. Fold gauze from left to right over pad. Turn in cut edge at right about 1 inch (2.54 cm.) then fold from right to left over pad. Turn pad over muff ends on face of pad.
5. When pad is complete, if all measurements have been carefully followed, there should be a margin of non-absorbent cotton about ¼ inch (6.3 cm.) wide on all sides of the zorbik envelope.
6. Sew along back and ends with medium sized stitches if necessary.
7. Tie in packages of ten with the face side up, except the top one which should be face down; thus a cotton side is exposed on top and bottom of package.

4 x 6 inch (10.2 x 15.2 cm.) pads.

(A)

1. Cut the gauze 11 x 9 inches (27.9 x 22.9 cm.).
2. Cut the zorbik 9 x 9 inches (22.9 x 22.9 cm.)
3. Cut the non-absorbent cotton 4 x 6 inches (10.2 x 15.2 cm.).

(B)

1. Place one or two sheets of zorbik, according to the quality, on the table; under zorbik place a piece of stiff colored paper 3 x 5 inches (7.6 x 12.7 cm.).
2. Cover the paper with a thin layer of sphagnum.

3. Fold the zorbik from the sides and ends over the sphagnum, making a complete tissue enevelope.
4. Pass the zorbik envelope to a separate table for gauze.

(C)

1. Spread out the gauze with the long side parallel with the edge of the table; place on it the tissue envelope with the long edge parallel with the short side of the gauze, and about 2 inches (5.08 cm.) from the right side.
2. Over the tisue envelope place a thin layer of non-absorbent cotton and adjust it so that it extends beyond the tissue envelope, making about ¼-inch (6.3 mm.) margin on all sides.
3. Fold the gauze from right to left and left to right over the cotton.
4. Muff the ends of gauze on face of pad similar to other sphagnum.pads. Stitch the back and ends if necessary.
5. When the pad is complete it should be 4 x 6 inches (10.2 x 15.2 cm.)
6. Tie in packages of 10 with face side up, except the top one which should be face down; thus a cotton side is exposed on top and bottom of package. Pads 4 x 4 inches (10.2 x 10.2 cm.) are made in a similar way. The zorbik is cut 8 x 7 inches (20.3 x 17.8 cm.) and the gauze 10 x 7½ inches (25.4 x 19 cm.). Pads 2 x 3 inches (5.08 x 7.6 cm.) are also made similar to the 4 x 6 inch (10.2 x 15.2 cm.) pads. The zorbik is cut 4½ x 5 inches (11.5 x 12.7 cm.) and the gauze 6 x 6 inches (15.2 x 15.2 cm.).

In all cases a margin of non-absorbent cotton of about ¼-inch (6.3 mm.) is left.

The above method of making sphagnum dressing is quite different from that employed by the British who make about ten different sizes, according to the special use they wish to make of them. The encasements for these pads consist of a flat bag made of long cloth with fine enough weave to prevent the moss from sifting through. This bag is filled with the appropriate amount of moss and sewed up.

The Canadian Red Cross has adopted three types of sphagnum dressings: the British type just mentioned; a "standard dressing" similar to that made by the American Red Cross; and a bed pad made of second grade moss. During the year 1918 the Canadians concentrated most of their energy

on the standard dressing, making less of the British type and comparatively few of the bed pads.

From October 1917 up to the time the armistice was signed on the 11th of November, 1918, the Northwestern Division of the Red Cross had made 10,000 of the British type and 540,000 of the American type of sphagnum pads. Of this number 60,000 were made at the University of Washington, partly by the students and partly by interested persons in the vicinity of the University. In addition to these there are standing orders which (Feb. 1919) have not been countermanded, from the base hospital at Camp Lewis, for 600 pads a month of the following sizes: 4 x 6, 4 x 4 and 2 x 3 inches (10.2 x 15.2, 10.2 x 10.2, and 5.08 x 7.6 cm.); and from the base hospital at Vancouver for 1600 pads a month, half 7 x 7 and half 4 x 6 inches (17.8 x 17.8, 10.2 x 15.2 cm.). The making of sphagnum dressings, however, was suddenly curtailed when hostilities on the western front in France ceased. The order for a million pads which had just been begun was immediately reduced to 40,000, which were practically completed a month later. In making these pads 18 Chapters as conveniently located to the source of supply of the moss as possible were selected. In the state of Washington these were Seattle, Tacoma, Bellingham, Everett, Thurston County, Pacific County, Aberdeen, Hoquiam, Montesano, Chehalis and Vancouver; in Oregon, Portland, Astoria, Lane County, Willamette County, Corvallis, and Marshfield; and in Alaska, Juneau.

The Atlantic Division has also been doing sphagnum work but has been somewhat hampered on account of the lack of suitable moss conveniently located. In spite of this handicap, however, the model workroom in New York City, where practically all this work for the Division was done, turned out for overseas 45,540 pads. This work was carried on under the direction of Mrs. Austin R. Baldwin.

Inspection of Sphagnum Pads

Sphagnum pads should be made under the personal spervision of a qualified instructor. It is of the greatest importance to have the most rigid inspection while the pads are being made, as it is easier to detect errors at that time than it is after they are completed. The following suggestions are offered to assist in the supervision and inspection:

1. At least two persons should be present when any box is packed to verify the count and see that all the directions are followed. The Chapter records should show the names of the packers of each box.

2. Dressings must be tied in definite numbers 8 x 12 inch (20.3 x 30.5 cm.) pads in packages of ten each; 12 x 24 and 14 x 20 inch (30.5 x 61 and 35.6 x 50.8 cm.) pads in packages of five each. These should be arranged with face upwards except the last one which is placed face down so that the cotton side is exposed on the top and bottom of the package.

3. Do not tie the packages very tightly, as the string may cut into the pads and break the tissue envelope, thus making the dressing useless.

4. There should be at least ½-inch (12.7 mm.) margin extending all around the pad beyond the edge of the zorbik envelope. This is absolutely essential for a successful pad, because when the zorbik envelope approaches the margin of the pad it acts like a lamp wick, carrying the water to the back of the pad, thus nullifying the usefulness of the non-absorbent cotton.

5. In the inspection of sphagnum dressings the main point to be kept in mind is to have a pad that will do the work required of it. If it fails to do this the pad must be made over in the Chapter, but do not become fussy about minute non-essential details.

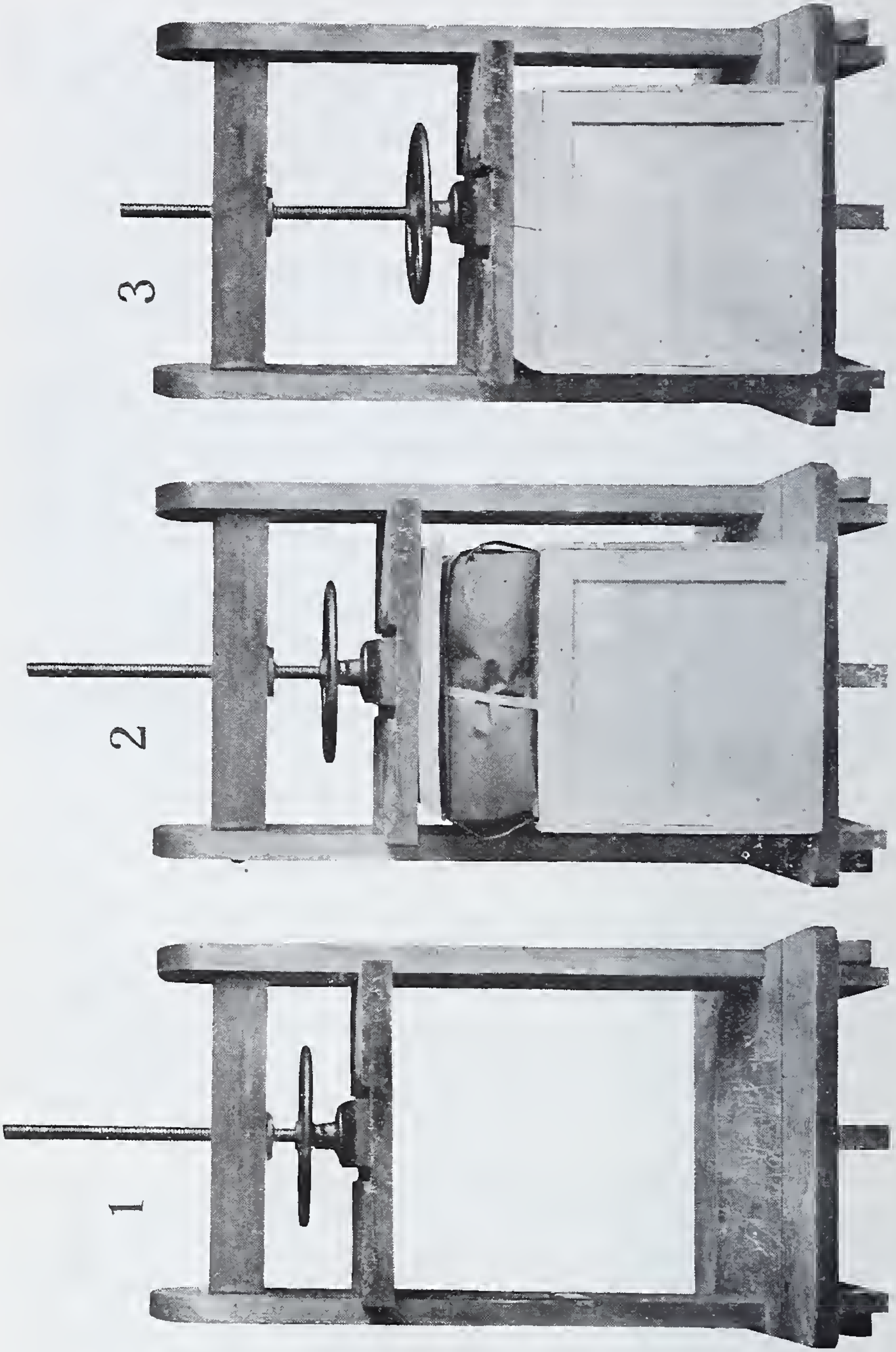

PLATE 48.

Mode of packing sphagnum pads at the Portland Chapter of the Red Cross, a saving of labor and shipping space. Figures 1 to 3 are successive steps in the process.

Labeling

1. The labeling should be clear, concise and accurate so that anyone unpacking the case of dressings at its destination can see at a glance the type of dressing and the number in each package.

2. Each package should be labeled. If tied with pieces of selvage, stamp the label on the selvage. If tied with cord, use manila tags.

3. The label should give the following information:

(a) 10 Sphagnum Absorbent Pads 8 x 12 inches (20.3 x 30.5 cm.).
N. B. The cotton side does not go next to the wound.

(b) 5 Sphagnum Absorbent Pads 14 x 20 inches (35.6 x 50.8 cm.).
N. B. The cotton side does not go next the wound.

(c) 5 Sphagnum Absorbent Pads 12 x 24 inches (30.5 x 61 cm.).
N. B. The cotton side does not go next the wound.

Packing

1. Line the box carefully with standard waterproof paper. This must be overlapped at least 2 inches (5.08 cm.) at all corners and edges. In order to prevent the waterproof paper soiling the pads, the box should be innerlined with common wrapping paper. Kraft paper is not necessary.

2. The packages of pads may be placed flat or on their edges but must not be doubled or crushed.

3. In case a press is used in packing, the pads must all be laid flat as otherwise they will be broken. In order to save shipping space and, incidently, manual labor in packing sphagnum dressings, the Portland Chapter adopted a method of pressing their pads, taking their cue from an old cider press. A photograph of this press is shown in plate 48.

The sterilization of sphagnum pad is done after they reach their destination just before they are used. The heat and pressure used in sterilization by an autoclave tend to make the moss brittle and to lessen the absorbency, but not to such an extent that its usefulness is serioully impaired.

Conclusion.

The great demand for sphagnum has largely been the outgrowth of the world war as a result of the tremendous need for surgical dressings and the acute shortage of cotton for explosive. Now that the war is over that pressing need has been removed, and for the time being the making of this kind of dressing for war purposes is almost completed. However, the inexpensiveness of the moss, its high absorbency, its abun-

dance in certain parts of the country and its undoubted superiority over gauze and absorbent cotton for some purposes, clearly indicate that it is too important a dressing to let die with the war. If, however, sphagnum is used for dressings in a commercial way, quite different methods of handling must be employed. If the labor of collecting, sorting and making of sphagnum pads as carried on by the Red Cross had to be paid for at a living wage, it would make the cost of them practically prohibitive; so if these pads are to be commercialized a different and less expensive method of handling the moss must be employed—more machinery and less hand work. Considerable experimentation has been done pointing to a solution of same of these problems, and preparing the way to some extent for a commercial enterprise. In the first place progress has been made, specially in Scotland and Canada in using a fan-like apparatus for cleaning the moss. From figures obtained from Rev. Adam Forman, Beattock, Scotland, the machine used there for cleaning moss will do 16 times as much work as the people who run it can do by hand. This is the result of several actual trials. It thus appears probable that sorting or cleaning the moss can be done at least to some extent, by machinery.

In the second place, in connection with drying the moss, experiments carried on in Montreal, New York, and Seattle, all more or less independently of each other, have led to practically the same results, namely, that a successful system of drying sphagnum must take into account the proper adjustment of temperature, humidity and circulation of air. It would appear that artificial heat may be used to advantage and without seriously impairing the usefulness of the moss for surgical dressings if these factor are carefully guarded.

In the third place if the dressings are manufactured commercially, a modification in the mode of making the pads is essential. It would never pay to make them in the elaborate fashion that the Red Cross has done where free expert assistance was almost unlimited. The writer has experimented sufficiently at least to satisfy himself that the moss can be prepared quite inexpensively in large sheets which may be varied in thickness according to the probable demand on the absorbency of the pad. These sheets can be cut into the particular size required and covered in an appropriate manner.

Finally, the writer wishes to express his appreciation of the efforts of all who have so loyally supported the cause of sphagnum in the Northwest. He is particularly indebted to Mrs. Henry Brakel and Miss Evelyn Gill Klahr for giving instruction in making sphagnum pads in the Northwestern

Division; to Prof. Albert Sweetser of the University of Oregon, Special Field Agent for the Northwestern Division, for the location and collection of sphagnum in Oregon; to Mr. L. L. Buch, Special Field Agent in Pacific County, Washington for locating moss and directing the collection; and to the University of Washington for making it possible for many of the experiments herein recorded to be carried on.

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During the last four years a considerable number of articles have appeared on sphagnum in its relation to surgical dressings, many of them as newspaper articles or local news items, both in Great Britain and America. The following are the more important articles that have come to the writer's attention:

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QUALITY AND VALUE OF IMPORTANT TYPES OF PEAT MATERIAL.*

A Classification of Peat Based Upon Its Botanical Composition and Physical and Chemical Characteristics

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THE PRESENT STATUS OF PEAT UTILIZATION.

The problem of peat utilization may be analyzed from several points of view, but only a few aspects of the subject are of essential importance to emphasize at this time. Among the peat problems in question none, in the opinion of the writer, is so serious as the failure to realize the existence of the important grades or types of this material in regard to quality and their relative value for agriculture or other uses.

There is a growing recognition of the fact that the term "peat" is too general to be applied to plant remains essentially different in composition, which have different agricultural and technical possibilities, and which vary greatly according to regional distribution and typographic features, even in the same deposit. Not only a proper understanding by the layman appears to be wanting, but the necessary scientific foundation is still lacking in this country which would deal with the differences in botanical composition of the various peat materials and their corresponding physical, chemical, and other characteristics of practical importance to the farmer, the technician, the manufacturer, and the scientist as well. A recognition of these differences, it is believed, would emphasize to those using peat land the inherent possibilities and limitations of the organic materials. From the standpoint of the State agencies and local investigators this is a specific problem of an urgent character underlying the sound and rational use of such land. Neither the selection of peat deposits of practical value for certain crops or for specific technical purposes nor the close correlation which exists between the botanical composition of the different peat materials and its corresponding physical, chemical, cultural, economic, or other merits can be attempted successfully until consideration is

*Reprint Bull. 802, U. S. Dept. of Agri., Dec. 29, 1919.

given to the important types of this material found in this country.

It is precisely this information which would enable one to form a correct judgment concerning the structural profile of peat deposits which accumulate under the widely differing climatic, topographic, geologic, and vegetational conditions of this country; and it is this aspect of the problem that would supply the essential criteria concerning the manner of developing a peat area for specific agricultural or technical purposes, or for a combination of agriculture with a varied manufacturing utilization, where under the pressure of strenuous circumstances this development must needs be centralized near a scurce of supply of raw material to insure financial success.

If we attempt to formulate the status of peat investigations in the United States and compare it with that of Holland, Sweden, Austria, or Germany; if we appraise in these countries and our own the degree of success in utilizing the various types of this material directly applicable to certain forms of agriculture or to economic industries; or if we compare the respective results of scientific investigations and the literature on the subject, based upon well-established, definitely described classes of deposits or groups of peat material, we shall have to acknowledge that we are far behind the position we ought now to occupy by right of resources and opportunities. The lack of information on which a wise decision should be based and the absence of any prospect of continuous or satisfactory returns have led in many places to a lack of confidence and to the abandonment of attempts to bring peat-land areas to a profit-yielding basis.

On the continent of Europe much effort is now devoted to encouraging the development of distinct classes of peat land. Good and relatively poor peat areas are reclaimed at much less cost than was formerly the experience. It is principally through the detailed collation of information for many years past, regarding the formation, structure, and distribution of different kinds of peat deposits, and the botanical, physical, and chemical differences of the various types of their organic contents, as well as though the systematically conducted observations of the several field conditions to be considered, that a corresponding profitable and varied development in the use of these resources has been possible.

More and more in this country the demand is becoming urgent for information concerning peat materials which affect the productiveness and health of crops. Information is called for in estimating the value, the supply, and the possible range of usefulness of special grades of peat for specific crops or

for manufactures, for that yielding a satisfactory material as a carrier for bacterial organisms, for fertilizer purposes, for litter, fuel, or distillation products, and for other uses. Advice is needed to point out the difficulties to be avoided, especially when an area of peat land may be developed for both agricultural and technical purposes by communities or associations and may be made increasingly profitable because of the equal, if not greater, value of the underlying mineral soil for staple crops, for special forms of economic plants, or for intensified methods of farming.

There are many instances of failure of efforts based on impractical and previously discarded ideas which time and again have been tried on an extensive scale in Europe and in this country, only to meet the same experience. The traditional disregard for facts of a qualifying nature, or for drawing a plan having due regard for the existing factors and needs of an undertaking; the inability of scientific workers to understand or to compare critically each other's researches in the field of peat investigations, because the terms peat and muck are not qualified and because faulty conceptions regarding them have still an unchallenged place in the scientific literature of this country—these are some of the results of the present situation, and for both national and economic reasons they reflect indeed a serious condition.

Types of peat material, their difference in botanical composition, in disintegration capacity, and in related physical and chemical characteristics have been established in Europe by many years of experience and scientific investigation. They form an adequate basis in problems which deal with methods to be practiced in the development and cultural preparation of a peat deposit, such as the well-known "Veenkultur," the Rimpau cultural method, the German high-moor method, and others, or in operations where the removal of peat for technical uses and centralized power plants is practicable. Data such as those just mentioned, regarding the nature and behavior of the various types of disintegrating plant remains making up a peat deposit, are considered of special importance in drainage projects intended to be practicable from an engineering and agricultural standpoint; they are essential for an adequate method of dewatering peat materials that are found to be of value for manufacturing purposes. It is rather in the knowledge of the different kinds of peat material, the factors in the field which brought about their accumulation and determined their character. that a satisfactory basis has been found for the improvement of peat by means of suitable crops or by specific operations in the technical industries.

Few phases of botanical inquiry have received as much attention as the development and formation of peat deposits; yet information concerning them appears to be little known and still less considered in practice, though the classical investigations of Anderson (1),[1] Clements (4), Graebner (12), Lesquereux (16), Lorenz (17), Potonie (19), Sendtner (21), Sitensky (22), and especially the works of Fruh and Schroter (10), Grisebach (13), Steenstrup (4), Vaupell (23), and Weber (25) are not only comprehensive but fundamental in problems relating to the structure and content of peat deposits.

The attempt to establish a correlation between vegetation and any one factor of the environment is difficult, and though not all field work is of a nature adapted to throw light on this vexed question it has, nevertheless, been possible to make such a correlation in the lines of physical and chemical studies with types of peat material distinct in botanical composition and in degree of disintegration. Practically all the work is thus far European, and the leading investigations, notably those of Bersch (2), Birk (3), Feilitzin (9), Gully (14), Hoering (15), Minssen (18), Virchow (24), and Zailer and Wilk (26-27), follow for the most part modern botanical viewpoints and definitions.

The botanical, physical, and chemical nature of the different peat materials is of the widest practical importance, since it is in general more difficult to change the nature of the vegetable mass than to remedy its deficiencies, but almost equally important is the character of the mineral soil underlying the plant remains. The geological relations have their most important significance in the fact that decaying organic matter and carbonated water have a relatively high solvent action on the minerals of soils and rocks. This effect increases with the area covered by the accumulating masses of peat materials and especially with thicknesses in which oxidizing conditions are absent. Underlying and marginal soils derived from sedimentary, metamorphic, and eruptive rocks, both basic and acid, correspondingly affect the content and quality of peat materials in saline impurities and in acid, alkaline, or neutral reaction. Some of these rock formations yield marked amounts of soluble injurious salts.

Special climatic influence appreciably the disintegration of peat materials, the formation of organic colloidal debris, and the direction of movement or transport of dissolved mineral constituents (8). The reactions may lower the supply

[1]The serial numbers in parenthesis refer to "Literature cited" at the end of this article, page ....

and concentration of nearly all available essential plant-food constituents and thus effect malnutrition, a prevalence of plant diseases, and allow certain plants and microorganisms to outgrow others, or they may lead to local accumulations of salts at the surface of the peat deposit or at the margins and in the mineral substratum underneath peat accumulations. Cultural practices and drainage systems in no small measure may favor and accentuate both the contamination through the movement of underground waters or springs in peat materials with high decay capacity and the concentration of salts by seepage or by evaporation. More consequential still are the effects of a pronounced inland or a typical oceanic climate on the disintegration, absorption, deposition, and leaching phenomena. Aside from the presence of either an abundance or a deficiency of agriculturally desirable mineral constituents, the climatic contrasts give rise to classes of peat land which resemble closely the "Tschernosem" and the "Podsol" condition featured by foreign writers (11).

It is obvious, therefore, that those inquiries are likely to be most fruitful which are concentrated first of all on the fundamental problem of determining and characterizing the types of peat material which are representative of distinct regional divisions or geographic areas of the United States and reserve for later discussion the details of the structure and contents of special peat deposits which are considered to be either with or without great value or are selected as representative peat deposits for specific experimental or industrial purposes.

It seems to the writer eminently desirable at this time to give consideration especially to those chief types of peat material in this country which are characteristic of peat deposits in European countries; to emphasize mainly the grades or types which resemble or coincide with each other and whose botanical composition is based upon the remains of plants known to occur in Europe; and to characterize those phases which are preserved conspicuously in a similar stage of disintegration in this country, irrespective of their positional relationship in the different layers of a peat deposit. They alone demand consideration in the present state of our imperfect knowledge, partly because through the recognition of these types considerable progress can be made in the fixing of standards of quality and in securing their adoption; largely, however, because the physical and chemical characteristics of these types have been systematically worked out by European scientists and their investigations contain a number of import-

ant contributions which are of value for several lines of work in peat utilization.

In this country the character of several of the peat materials of both fresh-water and salt-water origin differs in various respects from that of the European Continent. This difference would probably necessitate a special grouping and series of standards. Under the varying conditions of environment existing over the great regions of the United States in which peat materials may be found, the resulting types and their relative values must, obviously, vary quite as much on account of the distribution of peat-forming vegetation and the effects of the regional geological conditions and climate as on account of the local topography or the nature and position of the ground water in and upon which the plant remains are accumulating. So far, however, as the characterization is based upon differences of botanical composition rather than the stratigraphic series or upon differences in the vegetational surface cover or regional or local modifying field influences, the lines of demarcation are simple and sharp. The general recognition of the botanical composition of peat materials would initiate a movement in the direction of effective use of specific peat-land areas, and it might bring about a more satisfactory coordination of scientific activities. There is little doubt that on some such basis as this a closer union of the several lines of research and farm practices would be mutually beneficial and scientifically as well as agriculturally and economically profitable.

How much there is need for information of this kind may well be illustrated by consideration of the following facts. In many instances projects of drainage and reclamation which appeared feasible from an engineering standpoint have proved unprofitable as an agricultural investment, mainly through the scant consideration of adequate agricultural criteria which would render the work advisable or the project economically sound. In most cases the result proved unsatisfactory through lack of information concerning the merits and adaptability of the peat materials and the nature of the field conditions limiting their possibilities. It is easily ascertained whether a deposit may be drained to the bottom or only through the deepening of the outlet channel or by diking and pumping. But the nature of the plant remains, their disintegration capacity and resistance to weathering, the amount of shrinkage to be anticipated, the influence upon them of marginal mineral soils, springs, and ground waters, the features which might impair the value of the mineral subsoil for future agricultural uses—these are not so readily deter-

mined. Too much care cannot be taken in the preliminary examination of peat land before proposing improvements. Through advisory measures it is possible to forestall mistaken effort, to weed out undesirable enterprises, to select such deposits as can profitably be left as permanent "water-storing" reservoirs, preserved in their natural condition, and to assist individual or co-operative attempts in maintaining in an efficient manner those projects which are approved by agricultural merit, by economic need, by favorable markets and transportation facilities, or by the promotion of public health.

On many of the peat deposits which are peculiar in their type of material, in acidity, or in salt content, imitation of practice has led to their use for crops grown in succession at the expense of other agricultural industries, such as tillage farming combined with pasture, live-stock, or dairy farming, which would have been more suitable and would more regularly produce profitable returns. It is to be regretted that practically no extensive use has been made of the grasses, cereals, and fruit trees which are suitable for peat-land types and could be profitably developed. The natural extension of crops possible on peat areas is deserving of more systematic attempts, because it will be necessary to devote unusual attention in the near future to protect reclaimed deposits of peat now under cultivation against preventable difficulties. The more advanced agriculture becomes, the more diversified are its crop activities and the less will be the risk which attends concentration in a single field of cropping activity. Any work with the view of determining what methods of diversified agriculture are best adapted to and would benefit a certain locality or region, whether carried on by private individuals, communities, scientific institutions, or manufacturing interests, would prevent a great deal of loss to the owners of peat land and others uninformed of the limitations of different classes of peat deposits and their materials.

With the greater interest in live-stock production, the value of many abandoned peat areas as potential beef or cattle producing lands will probably again become enhanced, and it will be necessary to devote more attention than has been given to mixtures of grasses best suited to the several types of peat material or to their drainage capacity. The fact is not to be obscured that the war-time readjustments, aside from labor problems and the demands upon transportation, will tend to increase rather than lessen the need to convert forage and other crops into higher priced finished products.

Another urgent necessity is the extension of desirable

peat-land areas for staple crops, notably certain cereals, if the land is annually to turn in its share and render its adequate service to the country and to the farmer. Special varieties of cereals, such as oats, rye, barley, and even wheat, are grown with success on northern European peat lands; their adoption in this country would contribute greatly not only to increased production, but also to the larger range of crop plants which is so essential to a sound and secure foundation of peat-land agriculture.

In European countries the cultivation of the better grade of cereals is carried on upon peat deposits covered with a layer of sand (the "Cunrau" or "Rimpau" method, in vogue since 1862) and upon peat areas from which most of the organic material has been removed. The practicability of combining the agricultural and commercial utilization of a peat deposit for the production of fuel and food is no longer a questionable procedure. The problem has been well solved in Holland, where certain types of material are removed partly on account of their value for manufacturing purposes; largely, however, because the mineral subsoil has an equally, if not greater, value for the production of garden truck and for staple crops. Of the two methods of developing peat land the practice of sanding peat deposits has not always proved satisfactory. European experience seems to show that the amount of injury from diseases is very small compared with losses in yield from causes due to the selection of peat areas which contained plant remains with an unfavorable decay capacity or in which there appeared in the sand cover, as time went on, relatively injurious compounds from the underlying poorly aerated organic and mineral subsoils. It is, indeed, not unlikely that similar conditions are the cause of the greatly lessened yield in the cranberry crop and other plant industries reported from some deposits in this country.

For reasons such as these, the writer feels justified in the opinion that a preliminary-survey method based upon qualitative as well as quantitative differences of peat materials, which determines their serial position in the profile structure of a deposit and their depth relation and condition of disintegration and which examines the character of the underlying mineral substratum and the nature of its ground water, would offer data which might be of general interest to various lines of peat utilization and would permit an estimate of the probable difficulties or tendencies making for failure. It would prove a more reliable means of arriving at the practical value of peat lands for an undertaking that faces agricultural or industrial utilization, or a combination of both, and it

would avoid the discrediting of interests which desire to utilize peat materials for technical and commercial purposes, for bacterial inoculation, as a filler with other fertilizer substances, as a stock-feed ingredient, as fiber, and in other specific ways. It has been the experience in Europe, and undoubtedly in this country as well, that, no matter how excellent the results for a time, certain field conditions qualify the manner and methods of utilization, while the use of some types of peat material introduces sources of failure. Prudence is the more necessary in the present instance because the characterization of any native local or regional types of peat material has not as yet been coupled with definite or even preliminary botanical, physical, bacteriological, or chemical studies. This is, indeed, a cause for regret, as it is felt that a more comprehensive understanding of important types of this material, if made accessible to workers in different lines of peat utilization, might bring about a more complete coordination of their activities. Mere imitation and undue duplication of effort would be removed through an intelligent conception by each of the connection between the character of the peat deposits, their diverse materials, their value, and the uses most likely to prove successful.

Definitions and Points of View in Classifying Peat Materials.

In an endeavor to classify in some degree the results obtained in the field, a complete understanding is possible only by the consideration of various viewpoints and the meaning of the terms used. Naturally, when attempting a characterization and the grouping into classes of peat deposits and types of their material, it is desirable first to formulate clearly the fundamental lines of work along which this problem may be approached.

This consideration is important, since any controling condition, whether relating to peat-forming vegetation units and their present distribution, to the character of initial stages of a vegetation series and the corresponding mode of accumulation of peat materials, or to the degree of disintegration and contamination of plant remains, very often compels the formation of a tentative basis upon which systematic observations may be secured. The nature of the results will depend, therefore, much on the question whether the variant plant material or the modifying, controlling, and differentiating factor of field conditions is to serve as the basis for a full characterization. Should the emphasis be placed upon the product or upon the formative process? Would the water table which controls the accumulation of peat and thus gives

rise, among other distinctions, to water-formed and land-formed types of material or would differences due to the botanical composition and the sequence of vegetation units forming peat give a more satisfactory working method? Are the quality and value of materials to be determined from the vertical series or profile structure of peat deposits or from climatic and geologic features?

Two clearly related but analytically separable propositions seem to stand out as the essential premises of future work in this field of investigation. The order in which these propositions are stated is immaterial; one is as important as the other, for each is correlated with the other. Any attempt toward clarity of terms and statements, any definite determination of criteria for the classification or selection of peat deposits and their materials for agricultural or manufacturing purposes depends upon and includes a twofold qualification: (1) The botanical composition and stage of disintegration of the peat materials in a deposit and (2) the controlling basic factors in field conditions. These constitute an effectual limitation to the degree of success obtainable. The numerous abortive attempts at utilization have invariably followed from neglect of one or the other of these essential qualifying factors. Upon the recognition of these depends whether the farmer and the technician are to work by chance or on scientific lines.

It is not within the scope of this paper to deal with an ecological account of peat-farming vegetation units, of the character of initial stages, or of series of developmental stages arising in an area of a particular region. These have been discussed elsewhere in considerable detail. (4; 5, p. 220-262).

The object of these notes is to call attention to the following terms and definitions:

Peat is an accumulation of plant remains in various stages of disintegration or maceration, laid down in a definite manner according to imposed modifying field conditions. For statistical purposes and for reasons of common scientific interest the use of the term "peat deposit" should be limited to an accumulation of plant remains of at least 8 to 10 inches (20 to 25 centimeters) in thickness when compact and well shrunk. In this accumulation the surface layer of living native vegetation or deposits containing more than 40 per cent of mineral matter must not be included.

Muck is a phase of surface peat material which occurs under topographic conditions permitting extensive weathering and the accumulation of large amounts of silt and clay.

Humus.—No definition can be given at present, since the well-known defects in the usual methods of humus determination have made it clear that the use of the term in its present meaning is not advisable either in statements relating to soils or fertilizers.

Marsh (fen), bog, heath, and swamp are terms used largely on account of the well-marked physiognomy of vegetation which they represent and because they are common names in many languages. The plant remains of each group accumulating as peat are among the most distinctive of peat materials, and the field conditions of each have a more or less differentiating character. The deposits are quite variable in origin and structure, but their structure is primarily dependent on the form of the land surface on which they are found and upon the height of the water table while they are formed. They are dealt with later.

The words "marsh" and "swamp," on the one hand, and "bog" and "heath," on the other, correspond in a very general way with the terms "Flachmoor" and "Hochmoor" used by most European writers. The line of distinction and the transition between them is, of course, nothing like as sharp as the terms would seem to indicate except in regions having climatic conditions where they reach their best development. "Hochmoor" is applied, as a rule, to a class of peat land which rises from the edges toward the middle and thus shows a convex upper surface. "Hochmoor," or "raised bog," develops typically in regions of high humidity or rainfall, partly on account of the habit of growth of the sphagnum mosses, which form the main component of the surface vegetation cover. "Flachmoor" represents a class of peat land with a flat or even a slightly concave surface. Often a distinction is made on the basis of chemical differences, especially the absence or presence of lime or of acid reaction, but this distinction is not exact.

Acidity may rise in various ways and it may persist only for short periods of time. A temporary condition of acidity is common to surface peat materials with insufficient aeration, weathering, or disintegration, due to the presence of carbon dioxide. It should be stated, however, that different peat materials may have different acidities, and much of the soil acidity may be potential rather than active. In bog types of peat, for example, acidity appears to be due partly to the absorbing capacity of the organic materials for bases, breaking up salts and liberating acids (14), and partly to the presence of end products of disintegration which are colloidal sub-

stances of an acid character. The activity of microorganisms and certain forms of fungi as acid builders in peat soils and the degree of activity and probable harmfulness have barely been touched by investigators (5). In the marsh types of peat, acidity is caused more frequently by the oxidation of sulphids in the underlying mineral soils or by drainage waters which have become acid through a variety of causes. In a few cases acidity is due to the long-continued application of artificial fertilizers, such as ammonium sulphate and others, that have been used on the soils too heavily. Although the cause of soil acidity and its direct or indirect effects on plants and on the physical, chemical, and biological conditions and processes of soils have been the subject of numerous investigations, any broad statement is unsafe at this time.

From the standpoint of the conditions of accumulation it is desirable to distinguish between transported peat materials, i. e., the group of peat types which were formed in open water and below the water level (the aquatic or allochthonous types of peat), and those which resulted from the preservation of plant remains on the spot actually occupied by the peat-forming vegetation units, the groups of peat material formed at and above the water level (the marsh, swamp, and bog, or autochthonous types of peat).

The group division represents the members of a linear genetic sequence or vegetation series which have the same general range of controlling field conditions, e. g., the positions of the ground-water level in relation to the surface. Regional divisions have not been taken into account at present, since they represent the broader relations of types of peat material and the marked differences which are associated with the geographic distribution of vegetation forming peat, with climate, geology, and physiographic relations.

A type of peat material is the individual member of a group and is based upon differences in origin, texture, color, etc., and in botanical composition of such plant remains as characterize the organic material most conspicuously.

Phases are differences in a type of peat not sufficiently well marked to justify a new subdivision; they are variations in composition of plant remains, in mineral matter, etc., and are in some respects correlative features of certain field conditions.

From the standpoint of the vegetation units forming peat, the layers of plant remains preserved more or less intact are much the more important. They furnish a record of the development and structure of peat deposits, and they repre-

sent a more or less definite series of different vegetation stages, each initiated, continuing, or terminated and replaced in response to changes of basic past and present modifying factors or field conditions. They indicate that of the many plants which occupied the area as an association, only the few forms or species that were dominant and of rather wide geographic distribution contributed to the formation of peat layers.

The course of the development of a peat deposit may have been complete or interrupted, complicated or recurring, according to the conditions which prevailed; the resulting layers of peat material are certain to be correspondingly continuous or fragmentary and isolated. Wherever peat deposits arise, whether in the conversion of wet flat-land surfaces or of basins and kettle holes, on uplands, along river channels, or at the coast, the essential nature of the process is readily established by a comparison of the serial and contemporaneous strata of a deposit. The record is indicated by the profile structure and can be ascertained and reconstructed only by actually probing the layers of plant remains and examining microscopically the more disintegrated materials.

The stratification of a deposit points therefore to changed life relations for the plants which formed peat; to disturbances which ensued through altered conditions of rainfall, of soil moisture and its content of mineral salts, or in the relation of precipitation to evaporation. Unfavorable topographic or soil conditions may even arrest the succession of vegetation and keep it stationary at a point far short of the possible development within the area, but significant is the fact that with further accumulation of plant remains the influence of local vegetational or topographic conditions becomes less marked, while that of the region or climate gradually increases in effectiveness. It is probably for this reason that the older or lower layers of peat deposits of the Scandinavian countries, of Holland, Germany, Austria, Switzerland, Finland, and Russia appear to have a surprising number of features in common with many of the peat deposits of the northern portion of the United States.

There is the possibility of using the present native vegetation together with plants characteristic of corresponding types of peat material as an indicator and criterion of conditions which may serve for a basis of estimating the agricultural and other possibilities of a peat deposit, provided the relation between the surface vegetation cover, the character of the profile structure, and the nature of the field conditions of the deposit is correctly interpreted. It is necessary to bear

in mind, however, that by itself the surface vegetation of any unstable stage in the development of peat deposits can not be regarded as being wholly significant in the determination of the latent possibilities of a peat-land area. Much more importance, especially from the standpoint of interests combining agricultural and technical utilization, should therefore be attached to the profile structure of a peat deposit and to the climatic and geologic differences of peat-land areas.

The arrangement of types and groups of peat material given below is, it should be repeated, a tentative one. It is presented partly from an ecologic point of view and deals, therefore, with a series of peat-forming vegetation units within a set of field conditions such as the writer has described elsewhere for Ohio (5) and Massachusetts (7).

The outstanding physical relationship is the water content of the initial area and its effect upon the character of the series of vegetation stages forming peat and upon the manner of accumulation of plant remains. This fact is of the greatest importance also from an economic point of view in connection with the improvements to be given a peat-land area. It may be accepted as an axiom that undrained deposits of peat contain about 70 to 95 per cent of water, which should not be reduced to less than 65 per cent if the area is to be used for agricultural crops. Drainage and desiccation of peat materials below 60 per cent of water content have been observed to decrease their capacity for disintegration and weathering. The fibrous organic material becomes brittle, inert, maintains its initial appearance for considerable periods of time, and does not become readily nitrified. Certain of the macerated and water-formed types of peat become hard and compact and are not easily penetrated by the roots of crop plants or by water and air. On the other hand, the dewatering of peat materials, especially the macerated types and the well-disintegrated phases of other types, to a water content of approximately 25 to 30 per cent is an essential requirement before they can be used for technical purposes. Desiccation is one of the outstanding problems in connection with the manufacture of peat into a finished product. Thus far, the employment of pressure or of drying other than by the natural action of sun, air, and wind has not proved economically feasible.

It is obvious, therefore, that the utilization of peat deposits for agriculture, for manufacturing purposes, or for a combination of both implies operations which appear in some degree antagonistic. They have been harmonized, however, but only through investigations which give information con-

cerning the quality and quantity of peat materials, the conditions of their formation, and the methods of development required before they can be made available sources of food, power, or finished products. On the continent of Europe industries which are dependent on peat materials for these purposes have been centralized and located in the vicinity of selected deposits situated conveniently with respect to cheap water transportation. Provision is made for contemporaneous and subsequent cultivation with crops for the purpose of operating the peat deposits at their maximum efficiency. Lack of knowledge of the efforts made along these lines by European workers over a period of more than a century is directly responsible for the failure which the attempts in this country have met.

A TENTATIVE CLASSIFICATION OF IMPORTANT TYPES OF PEAT MATERIALS.

In the following classification of peat materials all those data of a physical and chemical nature resulting from investigations of European types of peat have been summarized in Tables I and II which, in the opinion of the writer, may safely be applied to the corresponding types of plant remains found to occur in the peat deposits of the Lake belt, e. g., Ohio (5) and the New England States, e. g., Massachusetts (7), and present also in other States within the glaciated area of North America. For purposes of microscopic identification of plant remains the illustrations given in Fruh and Schroter (10) afford an excellent basis for analysis and comparison.

The Aquatic Group of Peat Materials.

Types of peat material (allochthonous) from open water and from shore stages of a vegetation series, of which the plant remains accumulate below the water level.

The peat materials are structureless or coarsely macerated, soft, or compact and sticky, especially in older and deeper strata. They vary in composition, texture, color, etc., according to the depth of water and the character of the water in the initial stages of the area or of the vegetation series; they are largely, though not wholly, composed of the more resistant residues of plant remains, bits of woody and fibrous material, fragments of root and shoot tissue, the outer coats or cellular organisms, and a finely macerated debris as an embedding or binding ground mass which has either partly or wholly lost all vestige of its original organic structure. To this is added in various proportions and from various

sources material of plant and animal origin, as well as dust, silt, etc., from the surrounding area, laid down by wind and current.

Several distinct vegetation units which grow either free floating, wholly submerged, or rooted and partly submerged in water may form at any level considerable and extensive layers of material by the constant accretion of plant remains. These peat-forming plants are represented today by a great number of species and individuals with semi-aquatic habits of growth in fresh and brackish water. Among them are species of Ceratophyllum, Potamogeton, Castalia, Nymphaea, Peltandra, Pontederia, Polygonum, Decodon, and to a smaller extent Typha, Phragmites, and other genera more typical of the later grass and sedge vegetation units. The maximum depth at which a number of the water plants and semi-aquatics can grow and accumulate as peat in situ varies with the clearness and temperature of the water, but it rarely exceeds 15 feet (5 meters) below the surface of the water level. Under conditions which accelerate the disintegration of organic material, as in regions having a moderate winter season or which give rise to ground water colored brown from the presence of suspended and dissolved organic debris, the filling of depressions is chiefly from the bordering marsh, bog, or swamp vegetation units.

Three clearly distinguishable types of peat derived from this vegetation are encountered frequently in the same deposit, which differ from one another throughout in texture, color, composition, shrinkage, and other characteristics. In some deposits, however, these distinctions intergrade or the material occurs wedged in as a ground mass among the interstices of woody or fibrous types of peat or it may be wholly absent.

The peat mass, composed of very small particles, possesses many of the properties of a colloid and is on that account of the greatest importance in the problem of dewatering the material for the growth of crops or for manufacturing purposes. It is difficult to remove the water content to below 80 per cent and when dry these types of peat may form gaping cracks and may shrink to one-fourth and even to one-eleventh of their original profile dimensions. They are easily tilled, but under cultivation in open crops readily become finely granular, forming a dustlike powder, almost impervious to water, probably caused by the absorption of air. Loss in yields from wind erosion and plant diseases appears to be a detracting feature in this group unless provision is made for windbreaks, irrigation, or for a cropping system that com-

bines or alternates with grasses, small cereals, and broad-leaved crops. The use of sand by mixing it or by covering the peat material with a layer of sand 6 to 8 inches (15 to 20 cm.) thick should be practiced with caution; the method increases in most cases the yield as well as the possibility for growing a greater variety of crops, including truck, cereals, and other staple crops, but losses have been reported due to the selection of unfavorable deposits of material.

Some of the materials are noteworthy because of the relatively high nitrogen content, while others contain more of the waxy, resinous, and other ether and alcohol soluble organic debris (see Table I) from shrubby or herbaceous evergreens. On account of the greater resistance to oxidizing and other agents and to bacterial action, this plant residue disintegrates slowly and tends to accumulate in considerable thickness. The high content of organically combined nitrogenous substances is mainly related to the botanical composition of the plant remains and their slow disintegration capacity. They are largely of protein origin, but partly chitinous, "coprogenous," in nature, being skeletal portions and egg cases of insect and other animal life, and to some extent derived from spores and mycelial components. They are extremely resistant to decomposition. A high content of nitrogenous peat substances should not be looked upon necessarily as an important factor in judging the manurial or soil value of peat and muck. Materials from other types of plant remains, though exhibiting smaller values of resistant organic nitrogen, offer greater possibilities for meeting the agricultural and other requirements for soluble nitrogen.

Features such as those described above, especially regarding the ether and alcohol soluble component, make the material valuable for fuel as peat powder or as machine peat in the form of air-dried brick-shaped blocks and for coking or distillation products, provided the ash content is low. They are relatively less desirable for agricultural purposes or for use in gas generators on account of the presence of the resistant components and pitch-yielding and soot-forming by-products.

Frequently the material shows a mottled coloring on account of the presence of sulphur accumulating either in a finely divided form, as small modules, as crystals of iron and lime compounds, or in organic combination. Ferruginous inclusions are likely to be unavailable or injurious when available; they generally add some shade of red or yellow to the peat material when air dry, or, more rarely, the bluish tint of the phosphatic iron compound "vivianite" (blue iron earth).

Contaminations of that kind in fields not suitably drained retard considerably the growth of crops unless the peat material is well aerated, underdrained, limed, or supplied with finely ground rock phosphate and potash-bearing minerals. As mud baths, the saline phases of these types are reported to have proved medicinally valuable, and in European countries they have become the centers of health resorts.

MACERATED TYPE.

"Mudde," "Sapropel," "Gyttja."

Reddish brown to deep brown, more or less macerated plant remains with a fine-grained, oozelike plastic to sticky ground mass in various proportions, which occurs as a filler or binding material in the interstices between the less easily destructible fragments of plant tissue. The material is derived indiscriminately from vegetation units bordering open water. Some of the original identity and form is retained in spores; pollen grains, seeds, leafy and other fragments of pondweed material, bits of smooth and pustulate rootlets, and in the corser woody, cuticular, or other resistant components. Animal derivatives, such as chitinized skletal portions and egg cases from insects, are frequent.

The data in Table I are intended to show the marked difference which may result from the presence of ether and alcohol soluble substances, nitrogenous compounds and products valued in the distillation of peat.

Seasonal admixtures of clay, silt, and sand produce, as a rule, thinly laminated gritty layers, with cleaverage planes which often contain leafy impressions, small stems, and other drifted material. The variations in mineral matter constitute phases of the type when the relative proportion, e. g., of iron, sand, silt, or clay, is above 40 per cent.

Table I.—Chemical characteristics of important types of peat material.

[The data given show the constituents of 100 parts of material, all being on the moisture-free basis except as noted. Abbreviations ("Authority" column), giving credit for data: B=Birk (3), M=Minssen (18), Z=Zailer and Wilk (26-27).]

Types	Authority.	Organic matter.	Mineral matter (ash).	SiO_2 and insoluble.	N.	P_2O_5.	K_2O.	CaO.	$Fe_2O_3+Al_2O_3$.	SO_3.	Extract. Ether soluble.	Extract. Alcohol soluble.	Extract. Total.	Elementary analysis C.	Elementary analysis H.	Elementary analysis O.	Elementary analysis N.	Coke (charcoal).	Tar and water.	Gas.	Calories.
Sec. A.—Aquatic group:																					
1. Macerated type—																					
	M.72	59.20	40.80	32.26	2.48			2.34			6.92	3.00	a3.93								3,249
Level not indicated	M.25	93.81	6.19	4.13	.86	0.03	0.01	.46	0.82	0.54	15.62	27.89	a43.51								6,839
	M.26	48.53	51.47	45.51	.69	.06	.16	.25	4.8	.30	5.29	10.88	16.17					b64.20	b25.50	b10.3	3,371
0 to 0.60 m. level	M.108	a15.22	84.78	76.84	.73			.40			.50	3.20	a3.70								
2.10 to 3.55 m. level	B.46	a93.57	6.43		1.70					.48	4.24	11.95	a16.19	61.21	5.55	24.55	1.70	c40.66	d59 34		5,540
3.40 to 3.90 m. level	B.33	a74.64	25.36		1.02													e36.50	d63 50		4,703
5 to 5.65 m. level	B.26	a22.74	77.26		.46					.40	.86	2.14	a3.00	12.94	.95	7.99	.46	c51.28	d48 72		1,102
2. Colloidal type—																					
	Z	96.44	3.56	.10	1.03	.04	.04	2.85	.18	.22	2.24	2.85	5.09	55.17	5.11	35.13	1.03				4,934
Level not indicated	Z	71.71	28.29		2.80						1.57	3.49	5.06	41.87	6.03	21.01	2.80				4,170
	M.27	70.96	29.04	20.44	3.68	.28	.13	4.58	1.99	1.24	.76	3.93	a4.69								3,846
20 to 120 cm. level	M.88	a46.46	53.54	49.37	.94			.35			2.91	5.89	a8.79					b68.10	b20.0	b11.9	2,583
0 to 40 cm. level	M.95	a43.96	56.04	3.75	1.98			30.23			1.13	2.91	a4.04								2,886
40 to 100 cm. level	M.96	a48.06	51.94	6.92	2.14			26.94			1.21	3.24	a4.55								2,099
3. Doppleritic type—																					
Level not indicated	Z. 1	96.01	3.99		.96						.49	.85	1.34	53.14	3.96	37.95	.96				4,881
	Z. 2	94.56	5.44	.44	.92	.03	.04	3.89	.35	.23				51.71	3.77	38.16	.92				4,686
Sec. B.—Marsh group:																					
Phragmites communis	Z	95.80	4.20	1.73	1.46	.16	.38	.73	.33	.50	1.82	9.59	11.42	47.74	6.22	40.38	1.46				4,344
4. Reed-grass type—																					
Fibrous	Z	85.35	14.65	7.51	1.86	.16	.24	.94	4.17	1.18	.96	1.47	2.43	47.15	5.12	31.22	1.86				4,262
Poorly disintegrated	Z	88.20	11.80	5.22	2.29	.16	.05	3.02	1.10	1.98	1.08	1.95	3.03	51.38	5.07	29.46	2.29				4,581
Largely disintegrated	Z	89.54	10.46	3.16	3.07	.17	.03	4.99	.49	1.32	.85	1.70	2.55	52.04	4.58	29.86	3.07				4,691
Wholly disintegrated	Z	87.15	12.85	8.49	1.88	.09	.26	.45	2.57	.78	3.68	3.97	7.65	52.88	4.65	27.74	1.88				4,754
0 to 20 cm. level	M.18	92.29	7.71	2.94	2.65	.09	.09	2.63	1.20	.56	1.61	5.65	a7.26								4,794
20 to 60 cm. level	M.19	92.71	7.29	.87	2.52	.11	.06	3.86	1.12	1.09	1.27	4.40	a5.67					b41.80	b27.0	b31.2	4,811
Upper layer	M.70	a70.91	29.09	17.14	2.37		2.58				.73	2.18	a2.91					b52.50	b29.7	b17.8	3,658
Lower layer	M.71	a57.16	42.84	28.17	1.25		1.40				.68	2.65	a3.33					b56.50	b27.4	b16.1	2,958
1.30 to 1.45 m. level	B.64	96.94	3.06		1.70													c33.78	d66 22		
Carex stricta	Z	93.97	6.03	1.95	1.29	.46	1.75	.54	.28	.36	2.09	8.76	10.85	47.79	5.76	39.13	1.29				4,173
5. Sedge type—																					
Fibrous	Z	96.16	3.84	.59	2.19	.06	.06	1.77	.42	.76	2.27	2.70	4.97	54.58	5.56	3.83	2.19				4,993
Poorly disintegrated	Z	96.03	3.97	1.56	1.63	.07	.04	.50	1.40	.28	2.96	7.13	10.09	58.55	5.71	30.14	1.63				5,226
Largely disintegrated	Z	96.49	3.51	.29	2.10	.05	.04	1.52	.99	.46	2.94	4.79	7.73	58.21	5.21	30.97	2.10				5,256

Table I.—Chemical characteristics of important types of peat materials—Continued.

Types	Authority.	Organic matter.	Mineral matter (ash).	SiO_2 and insoluble.	N.	P_2O_5.	K_2O.	CaO.	$Fe_2O_3+Al_2O_3$.	SO_3.	Extract. Ether soluble.	Extract. Alcohol soluble.	Extract. Total.	Elementary analysis C.	Elementary analysis H.	Elementary analysis O.	Elementary analysis N.	Coke (charcoal).	Tar and water.	Gas.	Calories.
Wholly disintegrated	Z	94.32	5.68	1.09	1.32	.04	03	2.53	1.47	.28	6.25	6.02	11.27	58.25	5.63	29.13	1.32				**5,314**
Level not indicated	M.46	a94.12	5.88	1.61	3.07			1.9[illegible]			2.58	6.44	a9.02								5,212
	M.47	a94.88	5.12	.28	2.75			2.73			2.43	6.35	a8.78								5,235
	M.66	a79.14	20.86	11.77	2.22			1.36			1.51	a4.10	a5.61								4,055
Upper layer	M.10	93.88	6.12	1.37	2.94	.20	.06	2.75	1.12	.39	1.03	3.58	a4.61					b60.60	b33.7	b5.7	5,352
Lower layer	M.11	95.26	4.74	.40	2.47	.14	.05	2.60	.80	.45	1.57	4.53	a6.10					b36.90	b38.8	b24.3	5,387
Hypnum mosses—																					
H. sarmentosum	Z	97.19	2.81	.95	1.39	.13	.19	.52	.32	.43	1.73	2.96	4.69	50.71	4.66	40.49	1.39				4,477
H. trifarium	Z	93.84	6.16	2.30	1.23	.42	.28	1.43	.69	.30	1.21	7.44	8.65	45.98	5.62	41.01	1.23				4,157
H. scorpioides	Z	94.13	5.87	2.64	1.18	.24	.39	1.15	[illegible]	.26	1.48	6.9[illegible]	8.43	46.30	5.63	41.02	1.18				4,194
6. Brown-moss type—																					
Fibrous	Z	92.39	7.61	1.46	2.06	.07	.12	3.00	.37	2.25	.94	2.24	3.18	49.73	5.27	35.33	2.06				4,519
Poorly disintegrated	Z	94.27	5.73	2.73	2.25	.08	.08	.43	1.78	.42	2.37	5.04	7.41	54.8[illegible]	5.79	31.41	2.25				4,774
Largely disintegrated	Z	96.68	3.32	.26	2.08	.05	.05	1.14	1.29	.42	2.90	4.23	7.13	56.23	6.08	32.29	2.08				5,041
Sec. C.—Bog group:																					
Sphagnum mosses—																					
S. acutifolium	Z	97.58	2.42	.84	1.21	.11	.39	.33	.14	.23	1.27	3.87	5.14	48.23	5.33	42.81	1.21				4,521
S. cymbifolium	Z	97.13	2.87	.81	1.08	.10	.18	.99	.15	.25	.93	2.58	3.51	48.62	5.31	42.12	1.08				4,521
7. Bog-moss type—																					
Fibrous	Z	98.07	1.93	.34	.89	.06	.11	.28	.27	.15	1.16	2.98	4.14	48.60	5.12	43.46	.89				4,551
Poorly disintegrated	Z	99.36	.64	.18	.79	.05	.06	.12	.07	.08	2.33	4.24	6.57	50.25	5.27	43.05	.79				4,723
Largely disintegrated	Z	96.79	3.21	.49	1.35	.05	.05	1.78	.3[illegible]	.30	4.22	5.50	9.72	55.54	5.46	34.44	1.35				5,283
Wholly disintegrated	Z	96.08	3.92	4.04	.88	.04	.10	.08	.44	.11	5.58	11.16	16.74	59.82	4.93	30.45	.88				5,447
25 to 45 cm. level	M.3	98.19	1.81	.82	.69	.03	.02	.22	.20	.20	2.72	6.48	a9.20								4,814
50 to 70 cm. level	M.4	97.85	2.15	1.17	.64	.04	.03	.20	.2	.18	2.26	5.6[illegible]	a7.88								4,706
0 to 30 cm. level	M.35	96.83	3.17	1.69	1.37			.23			2.0[illegible]	6.93	a9.61								4,698
150 to 180 cm. level	M.40	a98.14	1.86	.57	1.18			.20			4.0[illegible]	9.15	a13.17								5,104
270 to 300 cm. level	M.44	a98.30	1.70	.30	1.39			.27			6.46	12.55	a19.01								5,484
0 to 2 m. level	B.22	a97.40	2.60		.96					.44	2.37	5.76	a8.13	51.40	5.90	38.72	.96	c31.67	d68 33		4,744
2 to 3 m. level	B.23	a98.41	1.59		1.08					.36	6.02	12.72	a18.74	57.05	5.49	34.32	1.08	c36 03	d63 97		5,455
0 to 1.2 m. level	B.42	a98.44	1.56		.65					.38	2.96	9.36	a13.32	47.52	5.93	43.86	.65	c31.06	d68 94		4,631
1.45 to 2.10 m. level	B.45	a97.47	2.53		.84					.25	5.90	19.60	a25.50	55.12	5.47	35.82	.84	c40.86	d59 32		5,485
Scheuchzeria palustris	Z	95.95	4.05	.40	1.85	.28	.77	.88	.93	.30	1.74	6.70	8.44	49.07	5.77	39.26	1.85				4,417
8. Arrow-grass type—																					
Poorly disintegrated	Z	96.20	3.80	2.19	2.62	.31	.04	[illegible]	.77	.11	3.19	4.30	7.49	54.82	5.94	32.82	2.62				4,968
Fiber	Z	97.76	2.24	.49	2.15	.25	.14	.33	.72	.14	3.16	3.82	6.98	55.22	6.37	34.02	2.15				4,991
Level not indicated	M.7	96.43	3.57	1.54	2.09	.19	.07	.56	.91	.16	3.48	8.96	a12.44					b21.30	b42.5	b36.2	5,034
	M.48	a95.64	4.36	.99	2.01			1.50			4.69	8.90	a13.59								5,387
	M.53	a96.01	3.99	.54	1.77			1.73			4.47	9.33	a14.80								5,516
1.25 to 1.45 m. level	B.59	a99.03	.97		1.05						1.71	6.66	a8.37					c29.56	d71 44		
Eriophorum vaginatum	Z	98.06	1.94	.47	1.31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]

9. Cotton-grass type—																					
Poorly disintegrated	Z	99.41	.59	.05	.85	.02	.05	.11	.16	.12	4.69	8.81	13.50	58.58	5.00	34.58	.85	-----	-----	-----	5,188
Fiber	Z	99.47	.53	.14	1.26	.04	.03	.06	.13	.07	2.79	3.80	6.59	52.64	5.41	40.15	1.26	-----	-----	-----	4,906
Level not indicated	M.49	a97.02	2.98	1.32	1.33	-----	-----	.54	-----	-----	5.08	10.56	a15.64	-----	-----	-----	-----	-----	-----	-----	5,152
	M.50	a95.61	4.39	1.60	1.33	-----	-----	1.37	-----	-----	7.41	12.88	a20.39	-----	-----	-----	-----	-----	-----	-----	5,236
	M.51	a97.50	2.50	.77	1.19	-----	-----	.62	-----	-----	4.90	9.84	a14.74	-----	-----	-----	-----	-----	-----	-----	4,974
Calluna vulgaris	Z	98.88	1.12	.08	.83	.06	.18	.18	.23	.13	3.99	9.06	13.05	52.95	5.77	38.63	.83	-----	-----	-----	4,805
Calluna vulgaris, whole plants	M.32	97.13	2.87	.56	1.04	.23	.51	.67	.10	.23	6.60	24.72	a31.32	-----	-----	-----	-----	-----	-----	-----	5,295
Vaccinium oxycoccus	Z	97.70	2.30	-----	.76	-----	-----	-----	-----	-----	2.93	9.02	11.95	52.58	5.57	38.79	.76	-----	-----	-----	4,812
Sec. C.—Bog group—Cont'd																					
Vaccinimum oxycoccus, whole plants	M.129	97.37	2.63	0.07	0.91	-----	-----	0.78	-----	-----	4.69	22.41	a27.10	-----	-----	-----	-----	-----	-----	-----	4,941
Andromeda polifolia	Z	97.06	2.91	-----	.86	-----	-----	-----	-----	-----	4.47	8.12	12.59	52.33	5.90	38.00	0.86	-----	-----	-----	4,942
Myrica gale	M.130	98.56	1.44	.06	1.45	-----	-----	.36	-----	-----	3.43	17.28	a21.71	-----	-----	-----	-----	-----	-----	-----	5.039
10. Bog-shrub type—																					
Heath peat	Z	89.99	10.01	7.65	2.28	0.22	0.12	0.29	1.42	0.18	2.59	6.30	8.89	51.50	5.06	30.98	2.28	-----	-----	-----	4,690
Level not indicated	M.1	95.25	4.75	3.29	1.21	.09	.07	.22	.54	.25	3.30	9.28	a12.58	-----	-----	-----	-----	-----	-----	-----	4.879
	M.2	93.69	6.31	5.02	1.45	.12	1.06	.14	.50	.20	2.73	7.73	a10.46	-----	-----	-----	-----	-----	-----	-----	4,812
Sec. D.—Swamp group:																					
Deciduous shrub types	Z	98.40	1.60	.20	1.37	.04	.05	.54	.34	.32	3.78	5.53	9.31	59.64	4.80	32.59	1.37	-----	-----	-----	5,236
11. Alder type—																					
Surface layer	M.12	92.94	7.06	1.86	1.99	.10	.07	2.39	1.21	1.10	2.92	5.74	a8.66	-----	-----	-----	-----	b42.30	b31.5	b26.2	5.140
20 to 60 cm. level	M.14	91.46	8.54	3.90	2.23	.15	.06	1.77	1.87	.49	3.25	8.48	a11.73	-----	-----	-----	-----	-----	-----	-----	4.920
0 to 20 cm level	M.15	83.20	16.80	5.61	3.19	.15	.08	6.35	2.24	2.19	2.68	6.53	a9.21	-----	-----	-----	-----	-----	-----	-----	4,371
30 to 60 cm. level	M.16	87.20	12.80	1.99	3.09	.11	.08	7.39	1.31	1.64	2.97	6.95	a9.92	-----	-----	-----	-----	-----	-----	-----	4,700
3.10 to 3.30 m. level	B.38	a80.52	19.48	-----	1.31	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	c34.51	d65.49		-----
12. Birch type—																					
Poorly disintegrated	Z	97.82	2.18	.50	1.60	.05	.05	.53	.43	.49	5.28	6.85	12.13	59.19	5.60	31.42	1.60	-----	-----	-----	5,388
Partly disintegrated	Z	96.56	3.44	.68	2.29	.14	.03	.39	1.76	.29	5.22	6.69	11.91	59.02	5.77	29.48	2.29	-----	-----	-----	5,477
Level not indicated	M.8	97.40	2.60	.50	1.16	.06	.05	.59	.89	.31	3.90	9.14	a13.04	-----	-----	-----	-----	-----	-----	-----	5,520
	M.9	94.57	5.43	3.15	1.57	.05	.08	.45	.97	.32	6.36	12.58	a18.94	-----	-----	-----	-----	-----	-----	-----	5,537
3.15 to 4.25 m. level	B.24	a98.20	1.80	-----	1.31	-----	-----	-----	-----	.35	7.69	16.36	a24.05	57.29	6.01	33.25	1.31	c37.69	d62.31		6.007
13. Deciduous-forest types	Z	90.69	9.31	-----	.90	-----	-----	-----	-----	-----	5.27	3.84	9.11	52.14	4.54	33.11	.90	-----	-----	-----	4,734
3.70 to 4.60 m. level	B.12	a38.74	61.16	-----	.58	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	c44.46	d55.54		-----
0.80 to 1.50 m. level	B.73	a95.52	4.48	-----	1.73	-----	-----	-----	-----	.39	4.12	8.75	a12.97	-----	-----	-----	-----	c36.69	d63.31		-----
14. Coniferous-forest types—																					
4.60 to 6.35 m. level	B.9	a33 33	6.67	-----	1.59	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	c38.19	d61.81		-----
4.25 to 5 m. level	B.25	a98.37	1.63	-----	.86	-----	-----	-----	-----	.35	10.76	24.22	34.98	66.15	5.93	25.25	.86	c36.48	d63.52		6,615

a Data interpolated by the writer. b On basis of the air-dry substance. c On basis of combustible substance. d Volatile matter.

Especially interesting in this connection are the marly and diatomaceous accumulations, which on account of their importance are treated here as subtypes.

Characeous subtype. — Structureless, mainly calcareous plant remains, predominantly the deposition of calcium carbonate by green algae, such as the stoneworts Chara and Nitella; usually comminuted granular fragments, soft, friable, and cream colored to white when pure, yellowish to dark rusty red according to the amount of iron present, grayish brown to black and granular when admixed with herbaceous plant remains.

Shell-marl phases are quite common among various types of peat, but the shell remains from mollusks are not an important factor in the production of the larger or more extensive accumulations of marl. Inclusions, such as calcareous tufa, concretions and modules caused by blue-green algae or by bacterial precipitation, and flaky incrustations on semiaquatic plants, mosses, rhizomes of herbaceous plants, and a form of fine tubular material derived from mats stonewort buried essentially intact, are occasionally found embedded in the macerated types of peat material. Most of the calcareous sub-type of plant remains is covered with herbaceous organic matter, but outcrops and layers between beds of peat material are frequent in level valleys.

Extensive deposits of marl and of marly peat materials of other types occur mainly in regions underlain by rock formations containing limestone and in areas where streams, underground and spring waters, or the soil material adjacent to and underneath a peat area are derived from calcareous drift.

Sandy argillaceous, ferruginous, phosphatic, and peaty marls owe their names to their obvious admixture. Marly phases of peat are as a rule granular, grayish brown to blackish gray in color, and inclined to be high in available nitrogen when under cultivation. To restore a proper balance in the ratio of plant food constituents, they therefore should not be treated with nitrogenous fertilizers. Where the amount of lime is too high, crops tend to become chlorotic and are susceptible to nutritional disturbances.

Beds of pure marl are used in the manufacture of cement, and they furnish lime of value as an agricultural fertilizer.

Diatomaceous subtype.—Structureless, mainly siliceous material from plant remains consisting of diatomaceous shells admixed with a varying proportion of sponge spicules, spore cells, macerated or fibrous plant material, and drift debris; light gray in color and compact but of very little weight in

proportion to its air-dry bulk; pervious when free from impurities; blackish gray and plastic to sticky from variations in amounts of well-disintegrated herbaceous aquatic-plant debris; brownish, loose, and mellow when permeated with fibrous roots from grasses, sedges, rushes, and other plants.

The structural and color characterictics are sufficiently well marked in some deposits to constitute three phases in this subtype. It usually forms a well-marked layer at the greater depth of certain basin deposits, but it has been found also as a surface soil material, notably in a number of river valleys in the New England States.

The plant remains are derived from diatoms and other vegetation of miscrosopic size and simple structure, such as desmids; green algae and species of Utricularia, Lemna, Riccia, and others are members of the vegetation unit floating freely in the quiet water of ponds and rivers.

Agricultural practices and possibilities are relatively unknown. Species of Calamagrotis, Phalaris, and Carex form the dominant vegetation cover of siliceous deposits on meadows of which the subsurface soil consists of macerated peat materials.

Diatomaceous material has valuable abrasive properties. As "infusorial earth" it is often employed for filtering, insulating, non-conducting, or packing purposes, as an absorbent, and for making protective soundproof envelopes.

COLLOIDAL TYPE.

"Lebermudde," "Saprokol," "Dy."

Finely divided, distinctly gelatinous, plastic organic debris, olive green, yellowish brown, or greenish brown in color; dark gray to blackish brown, hard, and of the consistency of horn when dry. The material is in large part probably a flocculation product rather than the result of chemical reaction or other transformation, since it has been found mainly in basins which are fed by ground waters containing lime insolution or which overlie a calcareous mineral substratum. There appears to be nothing in this type of peat that may be interpreted as of algal origin. The very small particles of plant remains are chiefly fragments from an aquatic vegetation which probably covered the open water area to the exclusion of other plant life. The organic debris seems to be derived largely from light-colored parenchymatous rather than lignitic tissue or waxy and resinous components. Algal filaments are present occasionally, but less abundant than spores, pollen, seeds of water plants, animal

ejecta, and other derivatives. Representative data of a chemical nature are given in Table I.

The layer is a transitional one, since in position it occurs more commonly between a lower silty or clayey calcareous mudlike debris and an upper macerated type of peat.

DOPPLERITIC TYPE.

"Dopplerit."

Blackish, structureless, compact, somewhat plastic, and homogeneous debris of mixed origin. An organic complex (organic lime salt; calcic humate), which is partly an end product of disintegration combined with lime and which probably results from a reaction between disintegration, ooze-like and very finely divided fragments of a variety of herbaceous plants, soft, woody tissues, etc., in the presence of ground water from sedimentary limestones or calcareous drift. The type has been found also as a surface layer on peat lands which appear to have been subject to prolonged shallow inundation of water carrying organic debris in suspension. The material is hard when dry, resembling bitumen or lignite, occasionally of a shiny vitreous appearance resembling anthracite; it weathers into angular, irregular-shaped fragments which gradually break down into a fine black dust in overdrained fields. The chemical data in Table I are representative for this type of peat material.

A similar organic complex but mainly ferruginous in character is found in some peat deposits (ferric humate) which appears to arise in a like manner through the action of chalybeate ground waters.

The Marsh Group of Peat Materials.

Types of peat material (autochthonous) from meadow stages of a vegetation series in treeless wet places with a water table near or slightly above or below the surface, or partially submerged during part of the year.

The peat materials are essentially fibrous and somewhat felty or matted, formed in the main from roots and rootlets of plants (radicellate peat). Macerated plant remains, seeds, fragments of various tissues, and woody components from shrubs are present in moderate or large quantities according to the degree of inundation of the area.

The types are derived from various vegetation units, such as sedges, reeds, cat-tails, rushes, and grasses. If water-formed layers of peat material and their wind-blown or otherwise transported drift components described above are absent in the profile structure of a peat deposit, it points to the fact

that the conditions for the growth of plants and the accumulation of their remains are entirely different from those already discussed. The noteworthy characteristic is the presence of roots which traverse the old soil or the shallow bottom of mud. The network of roots, rootlets, and rhizomes with its entangled matted mass of aerial plant remains also shows that the area had an initial water table near the surface or above it during only a part of the year. To the degree in which the plant form a closed association and the rise of the water table is favorable for their growth, they become buried as extensive or fragmentary layers, essentially intact and fibrous or partially disintegrated. On account of the slight shrinkage of the plant remains, the respective layers which are "built up" in this manner may constitute several feet of a deposit, but further increases in thickness practically cease unless there is considerable disintegration and shrinkage in the material or a rise in the ground-water level from any cause.

When an accumulation of structureless or macerated type of peat material formed in large part by aquatic vegetation units preceded and reached nearly to the water level, peat deposits of this class show as a rule a fibrous matted layer, more or less sharply differentiated in structure from the peat material below it. By the constantly advancing growth of semiaquatic and marsh plants the fibrous materials may gradually extend over the shoaling water, sink as their thickness increases, and thus give rise to filled-in- deposits of peat. Water pockets are not uncommon as delimiting strata.

This has an important bearing upon drainage, tillage, and other operations, and upon the possible uses of the land. In planning drainage improvements it is well to remember that deposits not too well drained are safer than those overdrained and that in this respect the distance between ditches and tiles is usually more effective and important than their depth. For areas of greater depths of peat or with poorly disintegrated grades of fibrous peat material it is necessary to anticipate a gradual but certain subsidence to as much as one-fourth of the original thickness. The decrease in the elevation of the surface should be met, therefore, by a provision for deepening the gravity outlet or for drainage by means of pumps.

The marsh types of peat are among the most profitable for agricultural purposes, though several of them indicate in some instances the presence of salts which in sufficient quantity may injure certain cultivated crops. The nature of the mineral subsoil, whether clay or sand, may considerably affect the agricultural value and need for fertilizers, the

former responding, it seems, more readily to phosphates, the latter requiring phosphatic and potash manures, and to some extent lime. Marsh or fen types of peat are easily cleared and brought under cultivation, and they are suitable for a variety of crops if carefully drained or if the drainage channels are provided with check gates. Some of the types when over-drained are apt to become brittle and easily break down to light-colored "mull" or granular peat dust. This is especially characteristic of fibrous sedge and of brown-moss (Hypnum) types of peat. Moreover, marked differences may arise from the preponderance of semiaquatic debris undergoing weathering and disintegration. As surface material this blackish fine-grained component is almost impervious to water, probably due to the absorption of air. Windbreaks, preferably of alder, maple, and willow, are necessary to prevent injury from dust storms to seedling crops, but a rotation which includes broad-leafed crops or plants with a fibrous root system to hold the fine-grained debris would be more advantageous and would aid in maintaining a favorable water content at the surface of the soil if irrigation measures are not feasible.

The first crop to be planted deserves, therefore, careful consideration, as it materially affects the disintegration of the plant remains. On poorly disintegrated, fibrous phases of these peat types, potatoes and corn are considered desirable. Where droughts are of rare occurrence not much trouble has been experienced in keeping the ground water too low to injure crops of value in intensive modes of farming. Ferruginous peat material of these types would, however, prove more profitable if under cultivation for hay and pasture.

The value of these types for industrial purposes is dependent on several factors, most important of which are the degree of disintegration, the ash content, and the impurities. The blackish, compact, well-decomposed phases with less than 20 per cent of ash produce less soot or ether and alcohol soluble and pitchy substances than the types of peat which contain the resinous and waxy bodies (see Table I). They are therefore considered preferable for the manufacture of power gas in gas producers where by-products are objectionable and their recovery is not contemplated. As machine peat, thoroughly ground, pulped, and air-dried, they yield a fuel of good quality, generally near 3,500 calories; they are clean to handle, give a relatively intense heat, and are well adapted for smaller manufacturing or farming communities and for domestic uses. The brick-shaped blocks of machine peat that are allowed to air-dry slowly contract into a dense mass covered by a gelatin-like outer layer which is reported to be

a hydrocellulose rather than a resinous substance; it renders the machine-made product almost impervious to water, compact, and more resistant to breakage.

The coarser textured, partly fibrous phases of peat appear to be preferable for composting and as a filler for tankage or a base for compounding with fine-ground mineral fertilizers. After excavation the moist peat materials should be piled and stored in mounds 20 or 30 feet high and kept under cover if possible for at least six to eight months. During that time the plant remains shrink considerably in volume and undergo a slow internal heating, granulation, and carbonizing process, which may be aided artifically by means of pipes heated with "exhaust" steam. The material has been profitably employed for various uses, including those essential to agriculture and as powdered peat for fuel in blast burners, for firing steam boilers, and for other purposes. It has not yet been shown conclusively that this material will produce nitrates on a large scale if inoculated with nitrifying microoganisms, but culture beds of these types of peat would probably be preferable to other media (5).

REED-GRASS TYPE.

"Phragmites peat," "Schilftorf."

Fibrous peat material, consisting mainly of a network of smooth and pustulate rootlets and stout hollow-stemmed, long, flat-pressed rootstocks (closed at the joints) of the tall reed-grass **(Phragmites communis)**; to a less extent are present the plant remains from species of Typha, Phalaris, Glyceria, Carex, or Sparganium. Macerated aquatic debris is found in varying proportions. The material is light yellowish or reddish brown to rusty brown in color; older layers of this type are fairly compact, largely disintegrated, chocolate brown to blackish in color when exposed to the air, and frequently contain charred woody components. They are mottled in appearance when under poor drainage conditions, from infiltration and precipitation of sulphur or iron compounds.

The type is more commonly found in peat deposits of the Central and Middle Western States in layers of considerable thickness. As a peat-forming plant Phragmites is well distributed nearly throughout the United States, tolerant to brackish water and to ground waters which contain a variety of injurious mineral impurities in solution. This renders the surface peat soil liable to saline incrustations drawn from the deeper strata; it tends to retard or prevent the appearance of shrub and tree stages of vegetation and may result in injury to deep-rooting crops when the area is brought under

cultivation. On some of the deposits overlying pyritous shale or drift derived from private-bearing rock formations the presence of mineral acids may sensibly diminish the cropping value of the land. The accumulation of iron at the surface may continue, in part replacing the plant remains by ferric compounds and nodular concretions which vary widely in composition.

In Tables I and II have been summarized the more noteworthy data of a physical and chemical nature for this type of peat.

SEDGE TYPE.

"Carex peat," "Seggentorf."

(a) Light-brown or reddish to dark-brown, fibrous peat material, mainly composed of finely fibrous roots and pustulate rootlets of sedges (Carex spp.); more or less uniform in appearance and compact, though porous; often recognized by the presence of the coarser fragments of (triangular) sedge culms; occasionally present are the plant remains and sheathed culms of Scirpus spp. or the matted rootstock of Juncus spp. The macerated components from aquatic-vegetation forms and the finely divided debris which contains seeds, pollen, spores, and chitinous and other fragments may be present in varying proportions. Older and more disintegrated layers vary in color from dark brown to brownish black and readily become granular when weathering.

The type is derived from a diffuse stage of sedge marsh or wet meadow, formed in part by rushes and other grasslike plants which are usually present in many peat deposits; they are characterized very frequently by the dense clumps or tussocks of Carex stricta. Semiaquatic plants are abundant in the water-logged depressions between the tussocks of sedges, while many herbaceous plants find lodgment in such places on the drier ridges and hummocks.

(b) A subtype which is more characteristic in the transition series to the bog group of peat materials consists similarly of a finely fibrous feltlike network from rootlets and underground scale-like leaves and stem portions of a variety of sedges, but usually includes the thickish rootstocks of the buckbean (Menyanthes sp.) and the threadlike stems of several bog plants. The material is grayish brown to dark brown in color. It is not easily distinguished from the peat material formed by sedges which occupy open-marsh meadows, except, perhaps, for the occasional resinous and waxy components from bog, heath, and other plants and in the fact that the lower contact layers are often poorly differentiated from

Table II—Physical characteristics of important types of peat.
[Data from Zailer and Wiik (26-27).]

Type of peat material.*	100 parts of material.						Specific volume weight of material in 1 liter.	
	Moisture free.				Air dry, 25 per cent of water content, absorb—			
	Contain—		Absorb—					
	Organic matter.	Ash.	Water.	Ammonia.	Water.	Ammonia.	Ash content.	Weight.
							Per ct.	Grams.
Sec. A.—Aquatic Group.								
1. Macerated type	--------	--------	--------	--------	--------	--------	--------	--------
2. Colloidal type	--------	--------	--------	--------	--------	--------	--------	--------
3. Doppleritic type	--------	--------	--------	--------	--------	--------	--------	--------
Sec. B.—Marsh Group.								
4. Reed-grass type:								
Phragmites peat (fibrous)	--------	--------	--------	--------	--------	--------	14.65	217
Poorly disintegrated	86.02	13.98	888.1	0.89	666	0.67	11.80	277
Partly disintegrated	86.71	13.29	871.4	.98	653	.74	10.46	417
5. Sedge type:								
Carex peat (fibrous)	--------	--------	--------	--------	--------	--------	3.84	221
Poorly disintegrated	98.27	1.73	1,379.8	2.16	1,305	1.62	3.97	260
Partly disintegrated	96.03	3.97	1,122.4	1.09	841	.82	3.51	288
6. Brown-moss type:								
Hypnum peat (fibrous)	--------	--------	--------	--------	--------	--------	7.61	95
Poorly disintegrated	92.86	7.14	1,506.8	1.22	1,130	.92	5.73	157
Partly disintegrated	94.28	5.72	887.3	2.41	665	1.81	3.32	204
Sec. C.—Bog Group.								
7. Bog-moss type:								
Sphagnum peat (fibrous)	97.92	2.08	1,604.2	1.83	1,203	1.37	1.93	88
Poorly disintegrated	99.38	.62	1,635.5	2.64	1,226	1.98	.64	113
Partly disintegrated	95.87	4.13	524.1	2.02	393	1.52	3.21	157
8. Arrow-grass type: Scheuchzeria peat	96.16	3.84	1,210.3	2.24	908	1.68	3.80	162
9. Cotton-grass type: Eriophorum peat	99.46	.54	974.3	3.46	731	2.60	.59	121
10. Bog-shrub type: Heath peat	89.99	10.01	456.0	2.30	342	1.73	10.01	297
Sec. D.—Swamp group.								
11. Alder type:								
Alnus peat; poorly disintegrated	98.35	1.65	564.5	3.83	424	2.87	1.60	287
12. Birch type:								
Betula peat—								
Poorly disintegrated	97.91	2.09	741.8	.97	557	.73	2.18	242
Partly disintegrated	--------	--------	--------	--------	--------	--------	3.44	257
13. Deciduous-forest type	--------	--------	--------	--------	--------	--------	--------	--------
14. Coniferous-forest type	--------	--------	--------	--------	--------	--------	--------	--------

*Although no definite data are at present available regarding the physical characteristics of types corresponding to the numbers 1, 2, 3, 13, and 14, the designations of those types are here retained in order to show their relationship in the classification.

the structureless material which formed below the floating sedge mat. Pockets of water are not uncommon.

The plant remains in the bog-sedge subtype show a rather widely varying admixture of sphagnum mosses, cranberry (Vaccinium spp.), and other health plants. Among the sedges

Carex filiformis is especially active on northern peat-land areas in extending the floating marginal platform of a bog meadow.

The material of poorly disintegrated sedge peat is quite resistant to cutting, plowing, and weathering. It is inclined under excessive drainage to form a mull, or dust, which is peculiar also to a few other types of peat material.

Various physical and chemical data are given in Tables I and II, among which are the striking differences in ether and alcohol soluble extracts.

BROWN-MOSS TYPE.

"Hypnum peat," "Astmoostorf."

Brownish green to drab-colored, light, spongy, matted material, often laminated and porous in appearance, derived mainly from the entire plants of various species of Hypnum mosses or related forms and containing an interbedded admixture, in varying proportions, of finely fibrous rootlets from sedges, etc.

The material disintegrates rather poorly and becomes brittle when over-drained, breaking down into a dust, or mull. Older layers are blackish in color and appear more or less structureless.

The type is more generally a transition feature to the bog group of peat materials; it is found in peat deposits in the Northwestern States and seems to occur there in considerable thickness. In the Central and Eastern States it is found only in layers and pockets of irregular size, heavily admixed with the plant remains of species of Carex, Pharagmites, and other peat-forming plants. Tables I and II contain the more important physical and chemical data for this type of peat.

The Bog Group of Peat Materials.

Types of peat material (autochthonous) from bog-meadow and bog-shrub stages of a vegetation series in wet places, with the water table near or slightly below but rarely above the surface.

The plant remains are characteristically spongy and porous or matted-fibrous to wickerlike peat, somewhat resistant to disintegration, reddish, yelowish, and deep brown in coor. The interstices are filled with a macerated debris in varying proportions, often soft and oozelike, in which fragments of cell complexes are usually well enough preserved to be determinable. The resinous constituents and the threadlike rusty brown root fragments of heaths with mycelial fungi

are an important factor in lending the specific character and value to this group. In transition stages the finer debris or ground mass forms a considerabe portion of the material, with intergradations from structureless plastic-appearing substances discerned with difficulty to clearly recognize fibrous and woody fragments.

The materials are derived from vegetation units which appear first as scattered, more or less localized plant associations in the marsh stages of a peat deposit. It seems that the succession of marsh to bog has taken place far more frequently than recognized hitherto, since sections through the profile of the lower layers of peat deposits in many localities show clear evidence that the area was formerly occupied by marsh vegetation. Quite similar stratigraphic successions leading from marsh to bog recorded in the peat deposits of European moors have been recognized in this country. In lacustrine deposits, however, bog vegetation appears often as foreland communities and immediately following the semi-aquatic stages of a vegetation series after the accumulation of macerated structureless, water-formed peat has reached nearly to the water level. By means of much-branched interwoven underground stems and fibrous rootlets they border open water or completely surround it as a floating mat, which rises and falls with the seasonal variations in the water table or sinks and becomes buried as a layer of fibrous peat firm enough to support trees.

Bog-plant associations may occur in marshy and wooded areas of valleys and uplands, and they may form definite sedge or "grass" bogs, "moss" bogs, and "heath" bogs under field conditions which inhabit the natural growth of plants other than the bog xerophytes. They are believed to be glacial relicts from a former more general distribution of boreal plants, some of which are represented in Europe and Asia by the same or closely related species. Most of these plants are now confined to an area extending from the north Atlantic to the Mackenzie basin in northern America, in which they attain their best development, and to locations with high atmospheric humidity. In their southern limits of distribution they maintain themselves, it seems, on account of soil conditions which indicate physiological drought as distinguished from physical drought. A discussion of the selective action of the soil stratum which allows bog plants to outgrow others, the effects on certain cultural plants used experimentally, and the possible causes of physiological drought offered in explanation of this fact has been published elsewhere (5;20).

Where climatic conditions, such as high atmospheric hu-

midity, are especially favorable these plant associations may spread literally over adjoining land surfaces or move up well-defined slopes of low hills. If the ground water, designated aerial as distinguished from telluric, rises in proportion, they may react upon other vegetation units. In northern countries of Europe they build up high moors, invade forests, and destroy with their accumulation a part or all of the tree covering.

The peat materials of this group weather slowly if improperly drained, and they require fall plowing and freezing, with frequent packing by heavy rollers, to maintain good tilth and the upward movement of soil water. Of considerable practical movement is the fact that as a general rule the amount of mineral matter is very low in these types and that applications of complete mineral fertilizers and stable manure for inculation with beneficial soil microorganisms appear to be more effective in establishing a normal balance of plant-food constituents and of bacterial action than in any of the other groups and types of peat material. The cultivation of grasses for hay and pasture or of potatoes as a first crop and corn, preferably for silage purposes, are known to be profitable in the preparation of these peat types for other farming practices.

The shrinkage on dewatering is very much slower than that which occurs when marsh or swamp and aquatic types of peat are subjected to drainage operations. With underlying water-formed plant remains or with water pockets as deliminating layers, the accumulation of bog peat may settle to a considerable extent. A change in the elevation of the gravity outlet or drainage by pumping may later be the only feasible method of relief. It is important, therefor, in designing drainage improvements to anticipate a subsidence of 10 to 25 per cent in the original profile of the deposit. Many bog peat-land areas are now deteriorating because the drainage systems laid out by an earlier generation have not provided for this shrinkage or have been allowed to get out of repair. Where seepage waters and springs arise along the hills bordering the valley or basin, intercepting ditches are extended along the lower edge of the high lands and provision is also made for the annual removal from the drains of any iron or other compound, sand, silt, or invading vegetation. The washing in of mineral impurities should be restricted to the lateral ditches. Saline constituents when present in these types of peat tend to appear and to accumulate at the margins as iron pan and bog iron or in the form of irregular patches of concretions near the ditches or overlying

subterranean drainage waters and springs. The ground water supply, springs, and the mineral subsoil especially require attention in regions of rock formation which contain an excess of soluble salts.

Only the fibrous and poorly disintegrated surface layers of these types are of value as litter and mull if properly dried and shredded (Table I). A rapidly growing industry in Europe is using these plant remains for manufacturing purposes, and they are greatly to be recommended for use in this country. The materials are shredded by simple tearing machinery and passed through rotary sieves to separate the finer mull from the fibrous material, which may be used for bedding live stock, for insulation and packing, in the manufacture of special grades of charcoal for metallurgical purposes, of pulp, pads, fiber, or alcohol (by converting cellulosic components into sugar with diluted sulphuric acid). Shredded peat material from certain species of sphagnum mosses, relatively free from inorganic impurities and of uniform composition, has been used as surgical dressings for wounds and as pads for patients with dysentery on account of its high absorbent value. It is in many respects a good substitute for medicated cotton.

There is an increased demand in Europe for sphagnum mull products, the particles of which are not larger than one-eighth of an inch (3 mm.) in diameter, as an ingredient with molasses in stock feed for fattening purposes and to prevent disorders. Mull from sphagnums as well as from Hypnum mosses and fibrous sedge peat has been employed profitable for packing, as an effective deodorizer and disinfectant for use in receptacles holding waste animal matter, and as an absorbent of gases (Table II) and of the valuable nitrogenous material of stables. The advantages of mull as powdered fuel in blast burners are considerable and of great importance for certain localities. The firing is reported to give a higher fuel efficiency and is relatively smokeless on account of the intimate mixture with the air or gases used. Moreover, there is the possibility of regulating the supply required for complete combustion. The change from oxidizing to reduce flame and from low to very high temperatures can be accomplished quickly.

The poorly disintegrated phases of these types of peat make a very inferior grade of fuel. With the same treatment through pugging or macerating machines, they make a bulky product, light in weight (Table II), dusty and brittle when dry. The well-disintegrated layers of the same plant remains form a much finer grained, uniform, compact mass. The

methods and machinery employed for working bog types of peat material, either for use as litter and mull or for heat and power, as machine-shaped air-dried blocks of peat for direct firing, for gas generators, or for distillation products, should therefore be determined in each individual case by a careful preliminary examination. It is obvious that only such deposits permit successful development as provide not only the quantity and quality of peat materials required, but if utilized would not cause an impairment of the land value of the underlying mineral soil. In Europe the most profitable utilization has been a combination of both the technical and the agricultural possibilities to which the peat area may be put during and after the removal of these materials.

BOG-MOSS TYPE.

"Sphagnum peat," "Bleichmoostorf."

Loose, spongy, fibrous or matted-porous, often layered plant remains from the entire plants of different species of sphagnum mosses, usually with an admixture of other bog-plant material; light grayish brown, yellowish, or deep brown in color, according to the degree of disintegration and the species of moss predominating. Where the development of the layer has been gradual and the extension of the mat has become anchored or has been built up, the material consists of poorly disintegrated remains of moss with relatively small amounts of macerated debris and finely fibrous sedge peat. Fragments from heath plants are present in varying quantities.

In the floating-mat phase and in the deeper layers of bog-moss peat which are more advanced in stages of disintegration, the plastic or oozy component occurs in greater abundance. The material is dark brown to blackish in color and shrinks considerably upon drying.

Except in a few Northern States and in Canada the built-up layers of bog-moss peat are rarely of great thickness or purity in plant composition. Other peat-forming plants which usually accompany sphagnum mosses are the cranberry (Vaccinium spp.), sundew (Drosera spp.), arrow grass (Scheuchzeria.), cotton grass (Eriophorum spp.), Rynchospora spp., Menyanthes sp., various species of sedge (Carex), and others (5).

The rarity of sphagnum peat is noteworthy and, together with the rather restricted occurrence at the present day of "moss" bogs as compared with sedge or "grass" bogs and "heath" bogs, is interesting, since sphagnum mosses are by many considered to be the starting point and the type plant

association of peat deposits.

Considerable work has been done upon the physical and chemical features of this type of peat material, some of which has been summarized in Table I and II. Other correlative phenomena have been discussed in a previous publication (5, p. 386-392).

ARROW-GRASS TYPE.

"Scheuchzeria peat," "Beisentorf."

COTTON-GRASS TYPE.

"Eriophorum peat," "Wollgrasstorf."

These two types are generally a composite in the peat accumulations of this country. The plant remains appear to be rarely of the thickness of accumulation or homogeneity in composition recorded for European deposits. They are derived from bog plants which associate with or follow closely a zone of the sphagnum-cranberry stage of bogs in our northern deposits.

The peat material is rusty to reddish brown, rather coarsely fibrous from plant remains, such as roots, rootlets, leaf bases, and leaf fibres of the wool or cotton grass (Eriophorum spp.) and of the arrow grass (Scheuchzeria sp.), roughish from the clustering of culms with varying admixtures of the grayish to dark-brown partially disintegrated sphagnum mosses and the finely threadlike material from cranberry and similar heaths.

The coarser fibered Eriophorum component is quite resistant disintegration and to cutting processes. When relatively pure in composition Eriophorum peat is deemed of considerable value for textile purposes, the manufacture of cloth, and similar technical uses.

The type of material in which the plant remains from arrow grass preponderate consists of a reddish finely fibrous network of rootlets inclosing thin scalelike leaves and leaf bases of this plant; the peat material is inclined to be brittle when dry and breaks down into mull or peat dust. Chemical and other data are given in Tables I and II.

BOG-SHRUB TYPE.

"Heath peat," "Reisertorf," "Heidetorf."

Reddish to rusty brown wickerlike peat material, partly finely fibrous from rootlets, but with numerous small twigs forming a prominent proportion. The woody fragments are derived from roots, stems, and branches of various bog shrubs, mainly heaths; the macerated ground mass is more or less resinous.

The type is often accompanied by a marked occurrence of highly ferrunginous impurities either distributed through the mineral sub-soil as a hard impermeable layer or pan or in the form of bog iron on and near the surface. In coastal climates the bog shrubs show beneath the peat material a layer of leached-out whitish or gray sand of varying thickness; underlying it is a characteristic blackish or yellow to rusty brown iron-stained sand, which often contains much of the mineral material and organic colloidal complexes leached from the upper sandy layer. The soils when denuded of their surface covering of peat material appear to be unsuitable for ordinary farming practices unless well handled. Pans, however, are by no means confined to heath bogs; they often occur in forests and on certain marshy and cultivated sandy soils.

The plant remains in heath peat are derived largely from bog shrubs, among which Andromeda sp. and Cassandra (Chamaedaphne) sp. are the most prominent of the ericaceous plants. Other genera, such as Ledum, Vaccinium, Myrica, and Kalmia, are less numerous in individuals and not so general in their distribution as to give rise to specific types of heath peat. In some of the sphagnum-cranberry bog meadows they are present in sufficient numbers to make a dense thicket, thus shading and even destroying the vegetation which covers the ground. The plants spread rapidly by means of long horizontal underground stems, from which arise at intervals erect leafy branches.

Empetrum nigrum and Colluna vulgaris occur very rarely on bogs in the United States, but they are among the low evergreen heath shrubs in the bogs of Canada and occur generally on the bogs or high moors of northern European peat deposits.

The chemical and other data cited in Tables I and II relate to heath types of peat on high moors.

The Swamp Group of Peat Materials.

Types of peat material from coniferous trees and from deciduous shrub and tree stages of a vegetation series on a wet substratum with the ground-water table generally below the surface during part of the year, as in bog forests and pond swamps, or partially submerged, as in river and coastal swamps.

The peat materials are characteristically a shrub or a forest litter. The greater proportion consists of woody material; roots, trunks of trees, branches, bark, twigs, etc., in a tangled mass, are in all stages of disintegration and more

or less in such a state of preservation as to be determinable. In this are the remains from leaves, ferns, mosses, scales, the rootlets of herbaceous plants, and fungal hyphae and spores more or less plainly recognizable. The material which fills the interstices consists of semidecayed weathered tissue and granular debris of great variety, comparable in structure with amorphous water-formed peat material, but free from the more obviously transported drift of lacustrine and valley or estuarine deposits.

The most critical factor in origin is the position of the water table. Trees instead of herbs and shrubs take possession of a wet marsh or bog area and gradually become the dominant peat-forming plant cover if the average water level during part of the time is sufficiently far below the surface of peat accumulation to favor weathering and longer periods for decay and for the products brought about by beneficial bacteria and fungi.

The deciduous-tree stage forms the end of the vegetation series; it indicates that an approximate balance is maintained between the amount of peat accumulation and the rise of the water level favorable for the growth of trees and that disintegration and loss of plant remains go on each year at about the same rate as the addition to the deposit made from the mature forest Only when there is a marked and scufficiently prolonged elevation of the water table from any cause will plants of other vegetation stages reappear, establish themselves, and begin again the accumulation of peat materials.

Many factors may operate to affect the relationship of the water level to the surface, and the resulting types of organic material may vary, therefore, quite as much from climatic and other regional changes as from local features or artificial obstructions A number of layers of forest litter in a peat deposit containing stumps and roots of trees naturally must be interpreted to indicate an equal number of modified field conditions for peat accumulation.

The presence of roots of trees in the substratum soils of a peat deposit or its bottom muds and the details of stratigraphic sections are features of considerable practical importance. They point to the fact that the area under consideration is in widely different condition for peat deposition and for the disintegration of material from that of filled basins. Originally in a land area with drainage well established the water table became elevated, probably through varying coastal subsidence, accompanied perhaps by irregularities in barrier formation or, more likely, with the accum-

ulation of plant remains, and it practically maintained itself over the area of active peat formation in close adjustment to the growth of the plants holding back the natural drainage. Areas of that class of peat deposits can be drained to the bottom and rarely need the more elaborate drainage measures which aim to reduce the amount of overflow in swamps and marshes resulting from river inundation.

Attention needs to be called to the fact that the dominant timber component alone is not always significant of the capabilities of these types of peat material. The plant remains derived from evergreen shrubs, such as the azalea and rhododendron, or from deciduous undergrowth in forests may alter the value of the material considerably. This is well illustrated in the distinction made by some authors between the "mild humus" characteristic of deciduous forests, well aerated and containing beneficial soil organisms, and the "raw humus" found in coniferous forests in which decay-producing organisms are usually less abundant.

ALDER-WILLOW TYPE.

"Alnus-Salix peat," "Bruchwaldtorf."

BIRCH TYPE.

"Betula peat," "Übergangswaldtorf."

Brown to chocolate-brown peat material, wickerlike in appearance on account of the numerous small twigs and branches of alder (Alnus spp.), willow (Salix spp.), and other species of deciduous shrubs which form a considerable portion in the fibrous or fragmental plant remains. The woody components often consist of bark and other recognizable, slowly disintegrating parts from birch (Betula spp.), but with the exception of the resinous components the material is as a rule relatively soft, easily cut, and tends to become brittle and granular when dry, breaking down into blackish coarsely grained debris. Material which is well disintegrated or contains a large proportion of plastic ground mass takes on a compact structure and often resembles a hard substance when dry.

The plant remains are derived from shrubs, among which the alders, buttonbushes, and willows are the most common. Birch and ericaceous heath shrubs appear to be more numerous in individuals on peat deposits of the Northern States and in European countries.

The analyses presented in Table I and II are intended to point out some of the features of practical value to agriculture and to technical interests.

DECIDUOUS-FOREST TYPES.

"Laubwaldtorf."

Loose, mingled debris of partly decayed branches, twigs, bark, and other aerial parts of plants falling to the ground and becoming incorporated in a more or less disintegrated leaf mold, which contains also the remains of herbaceous forms, ferns, and other vegetation growing in a mature hardwood forest. The older material of the layer is usually brownish black, woody, granular, with an abundance of fungal hyphae. This debris characterizes the more fertile area, a large proportion of which is often brought under cultivation with a small expenditure of fertilizers on account of the finer texture of the well-weathered material and its aerated condition.

The types of most frequent recurrence but which at present must remain without further characterization are the maple-ash-elm (Acer-Fraxinus-Ulmus) type in swamps and bogs of the Central and Northeastern States, often associated with oak (Quercus spp.) and basswood (Tilia sp.) or with conifers, and the gum-maple (Nyssa-Acer) type in the swamps of the Southeastern States. The data in Table I serve to show the relative value of the European type of deciduous-forest peat.

CONIFEROUS-FOREST TYPES.

"Föhrenwaldtorf."

Reddish brown plant parts from evergreen trees or from a mixed stand of conifers and deciduous forest trees which differ much in their resistance to weathering and decay agencies. The proportion of fibrous or leafy material and of weathered products from shrubs and herbs is quite variable. The ground mass in which the more resistant components are embedded is soft, plastic, and under moderate draining conditions becomes granular rather slowly. In overdrained deposits it dries and shrinks greatly and frequently takes on the consistency of a compact substance, impervious to water, especially when resinous material comprises an important element in the woody components. Experience indicates that coniferous peat materials are likely to be of low value for intensive farming purposes, even several years after clearing.

For each geographical or climatic district there are usually representative tree species which establish themselves, first scattered, then in a zone near the shore of lakes or valley channels, and eventually cover the entire peat-land area. As they grow taller they intercept a large amount of light and thus eliminate and displace the herbaceous and even

shrubby undergrowth. The water of a heavy rainfall is held back sometimes to a considerable depth by the dense growth and tangle fallen vegetation, thus extending the swamp conditions over adjoining areas. The larger number of trees have a shallow superficial root system, which may be removed by various methods of clearing, such as brushing, blasting, pulling, or burning. The plan of "brushing out" the land, plowing shallow the first time, gradually increasing the plowed depth from year to year, and seeding the land to grasses and clover with rye or oats is believed to be the cheapest and best of any of the several methods practiced.

The several types of coniferous forests, such as the tamarack (Larix sp.), the northern white cedar or arbor vitae (Thuja sp.), and the spruce pine (Picea-Pinus spp.) of northern bogs, the cedar (Chamaecyparis sp.) and the cypress (Taxadoium sp.) of coastal and southeastern swamps, or the mixed type which is characterized by various conifers and deciduous hardwood species, must remain at present without further description. In texture and color the several peat materials appear to have much in common, though they are derived from the dominant species of trees representative of the region. The sharper contrasts are undoubtedly more prominent in the woody and resinous components and the other plant remains, as well as in the condition of their decay and in the manner of the accumulation, that is, whether the deposits are the result of river inundation or formed in isolated tracts, fed by seepage and springs, where drainage features are correspondingly very different. Table I contains the more important chemical data for a type of European conifer-forest peat.

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DOES PEAT GEOLOGICALLY FORM COAL?

The theory that coal is nothing more than solidified petroleum was first publicly voiced by Mr. Chesebrough, in 1873, and he has clung to it ever since. Recently he has caused to be published a pamphlet on the subject. Following are some extracts from it:

Water under intense heat from the earth is turned into steam and the steam is then decomposed, the oxygen being consumed and the hydrogen set free, which then combining with certain elements in rocks forms natural gas, which I believe to be the parent of all the bitumens and coal measures. This gas, seeking its outlet through seams in the rocks, combines with this soapy carbons, forming thereby the lightest gravity of petroleum, which, becoming liquid, follow the seams or veins in the fissures of the rocks.

In the course of ages of time these light petroleum streams are gradually condensed, becoming heavier in body, such as the crude oils found in the Pennsylvania region, and by still further condensation, the Virginian crude oils. These, in certain localities where the surface heat of the earth in past time has been greater, from the cannel coals such are found in Kanawah, Nova Scotia, Scotland and other locations, and from which the original kerosene was distilled before the discovery and use of petroleum in 1861.

Longer time and greater heat converts the cannel coal into bituminous coal such as is found in great abundance in West Virginia and other sections, and as a final stage, involving still longer time and greater heat, the anthracite coal is evolved, showing the entire evaporation of all its volatile matter. Such is the coal which largely exists in the Pennsylvania coal regions.

The truth of this theory, while upsetting the accepted dictates of geology, is nevertheless borne out by many existing proofs. The coal in all its forms (cannel, bituminus and antracite) lies in the original seams, which were originally streams of petroleum running through the rocky fissures.

The accepted theory that coal has been formed by the decomposition of vegetable matter, as laid down in the books, is based principally on the fact that stems of ferns, plants and stygmaria, are immersed in the body of the coal. This argument is not sound, because the decomposition which was sufficient to turn the vegetable matter into coal would have surely been equal to convert the ferns, stygmaria, etc., also into coal; but the reverse is proven—viz; that when the

streams or veins were originally liquid they picked up and immersed them from decomposition through the ages until the present time.

Geology has never been able to explain why all coal measures lie in veins, rather than great bulky masses, as would have resulted had the vegetable decomposition theory been true. Peat is undoubtedly the result of vegetable decomposition, and is found in great bulky deposits where the vegetable matter fell and was dried out.

Again, both peat and wood are converted by heat into charcoal, while all coals, under heat, make coke and cannot make charcoal. In some parts of the earth, such as in Trinidad, lakes of bitumen have been found, showing that petroleum has made its way to the surface in volume and spread out as a lake.

The chemical changes carried on by nature in the interior of the earth are most mysterious and wonderful, such as the production of gold, silver, lead and other metals and all the different gems and precious stones.

Science is hopelessly at a loss to explain these wonderful productions, and it is far easier to concede that all the coal measures result originally from petroleum hydrocarbons, and that these owe their development to the decomposition of water into steam and its released hydrogen into natural gas, which gradually, through the ages, thickened by heat and taken up saporific carbons from the rocks and the earth, developed petroleum, which became the parent, under varying conditions of time, heat and pressure, of all the bitumens and coal measures.

The great question as to where bitumen ends and coal begins is so intricate as to be insolvable, and the connecting link is so close as to show they belong to the same family origin. The production of natural gas is a continuous creation, now going on, and will so contiue while the life of the earth lasts.

MINNESOTA GOVERNOR ADVOCATES USE OF PEAT FUEL.

Frank P. Keating of Duluth, Minn., wrote to Governor A. A. Burnquist of Minnesota to ascertain what, if anything, the state could do to open the peat bogs on state lands to the manufacturer of peat briquettes.

The governor replied as follows:

"Your letter relative to the peat situation is much appreciated. I would be greatly pleased to see some private

corporation take hold of the manufacture of peat briquettes. Unfortunately the state has no fund for going into such an enterprise.

If private capital could be interested in furnishing the machinery I think there are plenty of owners of peat bogs who would be glad to furnish the peat at a nominal price. Every thing possible should be done to encourage the use of peat as a fuel."

PEAT IN CANADA 1918.

No shipments of peat have been reported since 1916. During the latter year about 300 tons, valued at $1,500, were shipped from a bog in Middlesex county, Ontario. In 1915 shipments were made from the Alfred bog, Prescott county, amounting to 300 tons, value at $1,050.

	1915		1916		1917		1918	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
Production......	300	$1.050	300	$1,500	...	.....	...	.....

(Mineral Production 1918—Dept. of Mines, Canada.)

THE PEAT INDUSTRY OF DENMARK.

The Danish production of peat for the years 1916, 1917, and 1918, was, respectively, 280,000 tons, 1,300,000 tons, and 2,250,000 tons. The year 1919 will probably show a reduction In 1918 the working capital invested in this industry was 58,000,000 crowns. At the average price of 40 crowns per ton, the total value of the peat production in 1918 was 90,000,000 crowns. When it is considered that 2½ tons of peat are equal in heat to 1 ton of coal, the peat production in 1918 substituted coal to the value of 126,000,000 crowns. The future prospects of the peat industry are not considered to be very good, the principal difficulty being the poor facilities for transporting the peat from the bogs to the consuming centers. Peat played a very important part in taking the place of imported coal during the war, and is now being used to a large extent on account of the coal shortage.

(The normal value of the crown is $0.268 in U. S. currency.) (Consular Report.)

NORWEGIAN PEAT PRODUCTION.

The Norwegian peat-bog owners association held its annual meeting at Christiania on November 18, 1919. The

following facts relative to the production of peat in Norway are taken from the speeches of some of the leading members of the above association. There are in the peat-bog owners association 1,253 members. During the year 1918 a school and experiment station for peat production was opened at Vaaler i Solver. During the same year 42 new peat-producing factories were established and 88,000 tons of air-dried peat were produced. There are about 12,000,000 maal (2,400,000 acres) of peat bog in Norway, of which about 1,500,000 maal (300,000 acres) are being worked. It is stated that the production of peat for the year 1919 is very small. (Consular Report.)

PEAT AS RAILWAY FUEL IN ESTHONIA.

The following is taken from the Esthonian Review for October 22, 1919:

Trials were made recently of peat as fuel on the narrow-guage State railway between Reval and Nomme. The results were quite satisfactory, it being possible to maintain an average pressure of 11 atmospheres and to feed the boiler by pumping. The trial lasted 53 minutes, and a distance of 10 kilometers (1 kilometer equals 0.621 mile) was covered. The boiler surface was 41 square meters (1 square meter equals 10.76 square feet) and the surface of the fire box was 0.86 square meter drawing a train of 7 carriages, each with four axles. The principal difficulties encountered were the large tender space required for storing the fuel on account of its light weight and the fact that it had to be fed by hand instead of shoveling. It was also impossible to close to door of the fire box, as the feeding was practically constant. It is intended to send an expert to Sweden to acquaint himself with the method employed for pulverizing the peat, which has the advantage of reducing the storage space required, as well as lessening the time required for loading and at the same time permitting a larger head of steam to be maintained.

GERMANY TO OPEN UP PEAT DEPOSITS.

According to Raymond Swing, Staff Correspondent of the New York Sun, under date of January 3rd. German Industry is launching a program of coal saving and priority which for scope and the cooperation it entails is the greatest united economic effort the Germans have yet made.

It includes also the repartition of all coal shipments to give priority to producers of raw and basic materials and

means the temporary closing down of numerous factories producing finished articles and a consequent increase in unemployment.

The programme is the work of the economic council of the Ministry of Economics and is composed of representatives of employers, of the Government and of the public under the chairmanship of Hans Kraemer, president of the Rotogravure Syndicate, the leading figure in the German paper industry.

Kraemer told The Sun correspondent that while the full program had not been sanctioned yet by the labor representatives, they approved a priority rule for the nitrogen industry which would assure a remarkable output of fertilizers of 60,000 tons a month and he felt confident of the immediate assent of the labor men to a priority rule for the soda industry and ultimately to the remaining priority provisions.

"The labor leaders," he explained, "are afraid of this short period of unemployment, yet they must acknowledge that while the plan predicates great privation at the beginning it is an ultimate insurance against unemployment." He expressed gratification over the decision of the coal miners to withhold their demands for a six hour day and to continue to work seven hours, adding:

"They were moved to this decision by the figures showing the amount of coal that German industry was receiving today in comparison with peace times and they realized that unless the amount was materially increased there was no hope for our survival. Our program is to increase the production of German fuel 30,000,000 tons annually, which will more than make up the 20,000,000 tons we are forced to deliver to France.

'We expect to attain the new maximum in three years. Already the extension of peat digging employs 60,000 men and rapid progress has been made in opening untouched peat fields, which abound in Germany. The work of extending the underground mines is going ahead also favorably although at this time it is limited to the Ruhr region.

In the Ruhe region most of the new homes for miners will be built. Homes will be erected also for the peat diggers, now housed in army barracks.

FERTILIZING PEAT WITHOUT SODIUM NITRATE

A large number of field experimental tests were made in Germany during the war to grow potatoes on peat land without using sodium nitrate as a nitrogen fertilizer. The sodium nitrate was replaced by ammonium sulphate and calcium

cyanamid. The results show that just as good results are obtained when ammonium sulphate and cyanamid are used, provided plenty of lime or other basic material is added to the soil. The results of the trials are reported by E. Gully in Deutsche Landw. Presse. 1918—Issue 61, p. 371.

PEAT AS FUEL.

G. de Clercq. (Chem. Weekblad, 1919, Vo. 16, p. 863.)

A short introduction describes the various kinds of peat found in Limburg. The methods of burning peat and the disadvantageous influence of the large water content of Dutch peat is then discussed. Mention is made of various uses of peat as fuel under steam boilers, in gas manufacture, and for heating. It is concluded that peat can best be burned in ordinary stoves with an underlayer of good coal (anthracite coke). In this way the peat is dryed and then burns quickly. Fuel briquets of peat are described.

DISTILLATION OF PEAT.

(J. des usines a gaz 1919, Vol. 43, p. 172).

An installation of Gaurdabassi and Gouillard continuous vertical retorts is described. These retorts are composed of several cast-iron elements, each of which is formed by 2 truncated asymmetrical cones joined by their larger bases, while the different elements are joined by their smaller bases. From each element a pipe conveys the gas formed therein to its respective condenser. The retorts are heated by producer gas; the heat ascends from the base of the retort to the top from whence it is returned through recuperators. The material is charged into the top element where it is dried. It then passes downward into the other elements, each successive one heated hotter than the preceding one, where the less and less volatile gasses are distilled off, until it reaches the last element heated to 1000° C where the distillation is completed. The incandescent coke is quenched here in a tank of water, which also hermetically seals the retorts, and is then discharged by a screw as fast as it is produced. Results show that from 100 kilograms of peat there are obtained 29-33 cubic meters of gas of calorific value of 3500, 40-45 kilograms of coke of about 6000 calories, 8 kilograms of tar, 8 kilograms of ammonium sulphate and 1.5 kilograms of acetic acid.

PAPER FROM PEAT.

L. Fabre.

The author describes both the Zschoerner and the Brin Process.

The Zschoerner Process for converting peat into paper pulp consist in treating the peat under pressure successively with varying strengths of caustic solution followed with a treatment of sodium hypochlorite solution.

The Brin Process is both mechanical and chemical. The first part of the process consists in disintegrating the peat between rolls in the presence of water. The fibres go through a preliminary mechanical cleaning and are then treated with caustic soda and afterwards bleached either with nascent cxygen or hypochlorous acid. (Rev. chim. ind. Vol. 27 p 175.)

PEAT FIBER.

E. Ulbrich. (Kunststoffe 1918, Vol. 8 p. 235.)

The material used for spinning in war time and designated as "peat fiber" consisted of the peaty remains of leaves of the scheidigen wool grass (Eriophorum vaginatum.) The older portions of the plant forms beds of bog moss (Spagnum.) The author discusses the use of such materials for textile purposes (based on patented processes) and gives illustrations showing the plant and fiber tructure and the yarns produced.

PEAT FERTILIZER.

G. H. Earp Thomas. (U. S. Pat. reissue 14,686.)

This patent refers to the original U. S. Patent 1,212,196 and describes a fertilizer prepared by mixing ground eel grass with phosphate rock and peat or other fertilizer materials containing nitrogen and phosphorous.

FERTILIZER.

G. H. Earp Thomas. (U. S. Pat. 1,309,723.)

A fertilizer is prepared by subjecting finely divided raw phosphate rock to the decomposing action of nitro-bacteria in a mixture which also contains an admixture of humus-like material (e. g., peat) which may have been previously treated to improve its properties as a culture medium by drying, sterilizing, neutralizing and mixing with other nutrients for bacteria.

DEWATERING PEAT.

N. DeLong (U. S. Pat. 1,312,521.)

The raw peat is mixed with a small quantity of an alkali; such as soda ash, which will attack the water-holding cells of the peat without combining with the water, the mixture is then exposed to the air to permit evaporation of the moisture.

PEAT FUEL MANUFACTURE

H. P. K. T. Neilson. (U. S. Pat. 1,317,936.)

This patent is identical with Br. Pat. 125,083 (see this Journal 1919. Vol. 12 p. 227.) The peat is ground in a ball mill in its native condition, where the cell structure is disintegrated, and the water allowed to drain off the resulting mass. It is then subjected to pressure to produce fuel blocks.

PEAT FUEL FROM WET PEAT.

S. C. Davidson. (Br. Pat. 134,326.)

The employment of artificial heat for the drying of peat, or its treatment by electrolysis, necessarily involve the consumption, in some form or other, of such a large amount of heat producing fuel, as compared with the relatively small result obtained, that artificial drying is consequently considered, from a commercial point of view, as entirely out of the question. The object is to so prepare the damp peat, which has been taken directly from the face of the peat strata in a well-drained bog, that, by mechanical means alone, its contained moisture of about 85 per cent. can be reduced to the necessary extent, to render it inflammable as an efficient fuel, after allowing it to mature for a few days. In carrying this invention into effect, the damp peat, after being brought in from the bog to the fuel factory, is put into a suitable mixing and masticating machine (such, for example, as the well-known type of mortor mixing machines) in sufficient quantity to constitute rather less than about a three quarter charge, and masticated therein until it attains a somewhat putty-like consistency, whereupon a sufficient quantity of a finely-powdered and ground together mixture is gradually added to the peat, while the mixing mill is still kept running, until a thorough admixture of the whole of the ingredients is effected. The contents of the mill are then discharged, and preferably left over in a heap for a day or two, in order to ensure full completion of the chemical action of the coagulating mixture.

MANUFACTURE OF PEAT FUEL.

C. M. C. Hughes. (Br. Pat. 136,584.)

According to the present invention the components are mixed together in a sold state or at a temperature not sufficiently high to flux the binder, and by the employment of water in admixture components, are brought into a moldable state, and this plastic mass, while still in the cold state, is then pressed into the desired shape of fuel block. The briquettes or blocks thus formed in the cold state are thereafter subjected to heat for a sufficient time to dry out the water and thereafter to flux the agglutinants and thereby bind the briquets. The main body employed is a carboneous body such as coke, breeze, furnace ashes, sawdust, peat, coal, and anthracite, in a suitable sub-divided condition. The binder components may be ground with carboneous body; the whole being done and mixed and pressed cold, i. e., at the prevailing atmospheric temperature. The water is added before, during and after mixing and before pressing in order to give the resulting fuel block or briquette sufficient cohesion for the subsequent treatment.

PREPARING PEAT FIBRE AND PULP.

C. Gumbart, (Ger. Pat. 303,834.)

The fibre is thoroughly washed free from all substances which would tend to bake together on heating, and the water then remaining in the cells is caused suddenly to expand by heating. The opening up of the cells in this manner has the advantage over the freezing method, that the degree of distension produced can be controlled by the amount of heat introduced up to the maximum effect obtained by transforming the cell water into steam.

CORRESPONDENCE.

Dear Mr. Editor:

Will you permit me as a Charter Member and a former Vice President of the American Peat Society to put before our present members a few suggestions.

We must all admit that in an organization in which the members are not only small in number but widely scattered, that the American Peat Society's Journal is practically our only means of communication and above all things the one bond that keeps us together. How this remarkably well edited and well written organ has steadily improved during

the past two years with the small means behind it as published in our Secretary's Report would be inexplicable were it not that we know that outside of actual expense in the paper and mechanical work it has been largely a Labor of Love on the part of those behind it. Peat developments are outrunning their capacity to take care of and properly record them, so I desire to make the following suggestions.

First that each member double their subscription for this year and send Ten dollars instead of Five and receive two copies instead of one.

Second that each member make it his or her special business to get at least one subscriber at the old rate, $5.00.

Third, that all interested members do all they can to boost the Journal of the Society generally.

The time is coming when you will see just one thing suggested in its columns that will more than pay you for all you contribute. I beg to enclose check herewith for $10.00 to start the ball.

St. Augustine, Fla. Very truly yours
Mar. 4, 1920. ROBERT RANSON.

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Send orders to Chas. Knap, Sec'y., 17 Battery Place, New York City.

Mr. Chas. Knap, Secretary,
American Peat Society,
17 Battery Place,
New York, City.

Dear Sir:—

I, the undersigned, being interested in the development of our peat resources and in the welfare of the peat Society, beg to make application to membership in your Society, for which I enclose $5.00 as annual dues.

Signed ....

Address ....

....

CONTENTS

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NOTE.

The publication of articles in the Journal of the American Peat Society is not an endorsement of the same by the Society or its officers. The American Peat Society is not responsible for the statements and opinions advanced by authors or correspondents. Written discussions on articles appearing in the Journal are invited. Correspondence and articles regarding peat and cognate subjects solicited.

ANNUAL MEETING.

The Secretary, Mr. Chas. Knap, of the Society, hereby notifies the members of the Fourteenth Annual Meeting of the American Peat Society.

The Annual Meeting of the Society will be held at Madison, Wisc., September 2nd, 3rd, and 4th, 1920, for the election of officers and the transaction of any other business which may properly be brought before the Meeting, including an amendment to the Constitution increasing the number of the Executive Committee from five (5) to nine (9), inclusive of the Officers of the Society who are ex-officio members.

All members should endeavor to attend this Meeting and thereby show their interest in the welfare of their Society.

The increasing development of Peat lands agriculturally; the growing demand for Peat by fertilizer manufacturers; the improvements in devices for handling and drying Peat; the advancements made in the conversion of Peat into practical fuel; should stimulate the pride of all members in their Society. They should realize the vast importance of the influence the Journal of the Society has exerted in this progress of Peat industry. By chronicling and fostering all developments of merit, the Journal has blazed the trail and led the way through the maze of ignorance and failure to the higher plain of enlightenment and substantial reward.

(Signed) CHAS. KNAP, Secretary.

Please note that the following amendments to the Constitution will come up for action:

Amendment to Constitution.

At the Annual Meeting held in Minneapolis, September 22nd, 23rd, 24th, last, it was

Voted: "That the President be given the power to increase the Executive Committee to nine (9) members, exclusive of the officers, that in this connection active members be favorably considered and that the Executive Committee transact business by mail and telegraph as usual."

This involves an amendment to the Constitution of the Society. Before it can be made effective, Article VII of the Constitution prescribes:

1. "That the proposed amendment shall have been first submitted in writing to the Executive Committee and shall have been approved by them, and

2. "That notice of the proposed amendment, so approved, shall be given to the members of the Society, at least thirty days previous to the Annual Meeting, and that the proposed amendment, in full or part, shall form a part of the notice of the Meeting at which final action is to be taken."

In conformity with the foregoing, the Executive Committee have filed their written consent to the proposed amendment with the Secretary of the Society.

THE EXECUTIVE COMMITTEE.

New York, April 22, 1920.

(Signed) J. H. Hoff, Chairman.

(Signed) Chas. Knap, Secretary.

First Vice President, Prof. A. R. Whitson, Agricultural Experiment Station, Madison, Wisc., is chairman of the local Committee and he can be assured of large and well attended meeting.

Members and those interested are cordially invited to prepare papers, and should send title, as soon as possible, to Mr. Chas. Knap, 17 Battery Place, New York City. Others not so prepared are requested to bring their peat information along and dispense the knowledge to others, whilst there will be plenty of chance to imbide from the spring of peat experiences.

Write the Secretary that you are coming and the Committee will do the rest. Make this a banner meeting, which has been arranged somewhat earlier than usual so as to be able to intelligently observe agricultural results from peat. It will be worth while, and moreover we want you with us.

VIRTUES OF PEAT IN SOIL.

Although we have frequently referred to this subject in our editorials*, there seems reason to touch again on the virtue of intelligently applying peat to soils, at the same time we would recommend that Prof. Levin's article "The Use of Peat as a Fertilizer in Michigan," appearing in this Issue, be read by all those interested in this subject.

Organic matter is a necessary component to make a soil productive. It tends to spread the individual soil particles further apart, especially in clay soils. On the other hand, it has a greater cohesive power than sand and consequently acts as a binding material in sandy soils, a condition much to be desired in this type. Better tilth is induced by the presence of organic matter, and ease of drainage and good aeration are facilitated. The moisture-holding power of the soil during the growing season is increased. Such conditions promote root development of plants, bacterial activity, and liberation of plant food. Practically all of the nitrogen of the soil is contained in the organic matter present. In general, the effect of organic matter is to better the soil in many ways as a medium for plant growth and to increase, either directly or indirectly, the available supply of plant food.

ITEMS OF INTEREST.

Prof. Ezra Levin's article in this issue, entitled "Muck Farm Management in Michigan" is one of the most practical papers ever published on this subject. Do not fail to read it.

Hennepin Atomized Fuel Company of Minneapolis, Minnesota have acquired 10 acres of peat land in Northeast Minneapolis, near Broadway and Johnston Street. It is intended to build a pulverized peat fuel plant. The peat will be excavated by the Garnett Process and pulverized by the Holbeck Pulverized Coal System.

G. F. Hancock of Chassel, Michigan, and owner of The Michigan Humus and Chemical Company has begun peat operations at Klingville, Baraga County. The Sturgeon River Swamp lies partly within Houghton and Baraga Counties, and is the deposit previously worked by the Fertile Chemical

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*See this Jour., 1919—Vol. 12, p. 5 and p. 112.

Company of Cleveland, Ohio. Fertilizer and fertilizer filler will be manufactured.

The Humus Natural Company, owned by John P. Beardall of Brooklyn, N. Y. is opening up a peat deposit at Branchville, N. J. Peat fertilizer will be produced at this plant.

Harley J. Speaker, Ohio State Orchard inspector, owns a peat bed 12 to 14 feet deep on Catawaba Island, Ohio. He plans to cut peat bricks to use next winter for fuel.

H. H. Hindshaw of Hibbing, Minn., has become indentified with the Mesaba Syndicate, organized for the purpose of utilizing the vast peat beds in and around Hibbing, Minn.

MUCK FARM MANAGEMENT IN MICHIGAN.*

By Ezra Levin

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There are approximately four million acres of the highly organic and otherwise distinctive soils in Michigan which are known as "peat" or "muck". Less than one percent of this area is under cultivation.

Celery, mint and onions are the most important crops being raised on these soils. The celery and mint lands of southern Michigan have received well deserved publicity from the distribution of these special crops.

The wrong impression of the proper methods of muck land utilization is often drawn from the successes reported from these special crops. Frequent failures have developed a serious skepticism among reliable agricultural observers as to the value of these soils, notwithstanding the fact that in Europe these soils are farmed extensively and are considered valuable.

The encouragement of the development of the muck lands of Michigan to any large extent by the production of highly speculative special crops such as celery, mint and onions is inadvisable. The future of the muck lands of Michigan is dependent upon the development of a diversified farm management plan which will be as safe and profitable as highland farming.

While grain and stock are produced on muck farms, it is

*Read at the Annual Meeting, Minneapolis, Minn., Sept. 24, 1919.

usually in conjunction with the adjoining highland. Stock farms on exclusively muck areas are not common.

It is the purpose of this paper to present the muck problem of Michigan, by designating the factors which underlie the development of a general farm management plan for the muck lands of the state, and by indicating the direction in which investigation appears urgent. Attempts will then be made to summarize the best known practices in muck land utilization to carry on profitable farming on these soils. For this work, the writer will draw upon his own experiences and his observations while carrying on extension work among the muck farmers of Michigan.

Soils formed by the accumulation of partially disintegrated residues of plants, the complete decay of which has been prevented by submergence in water, are termed muck or peat soils.*

The distinctions between these soils and so-called "high land" or mineral soils are strikingly shown by a current definition of **Soil** as given in one of our standard texts.

"The broken and weathered fragments of rock that cover in a thin layer the solid part of the earth, and that furnish the foothold, and in part, the sustenance for plant life, are termed 'soil.' "**

It is important to note, from the muck farmer's point of view, the inadequacy of this definition. Muck soils stand in contrast to mineral soils in that muck soils are organic in origin, produced as they are, almost wholly by a deposit of plant remains, and in that they contain an abundance of nitrogen (the poorest in nitrogen having a higher nitrogen content than our most fertile prairie upland). They are characterized by a large percentage of organic matter and a low total mineral content. Muck soils change rapidly,—chemically, physically, and biologically. These soils are distinct from highland soils in that highland soils are of mineral or inorganic origin, usually comparatively deficient of nitrogen and organic matter; and relatively very stable. While it is recognized that, beginning with blow sand containing a mini-

*Note: In view of the indefiniteness of the terms "peat" and "muck," the term "peat" will be arbitrarily used to refer to all formations as defined; and the term "muck" reserved for the portion of the peat areas which are utilized for farming purposes.

**Note: "Soils; Their Properties and Management," Lyon, Fippin and Buckman.

mum of organic matter, soils are found with increasing amounts of organic muck soils, the distinctions noted are clear between 95 percent of the muck soils and 95 per cent of the highland soils in Michigan and neighboring states. The importance of emphasizing these facts will be apparent as the discussion is carried on. It is obvious to the student of farm management, who has the vision of a paying system of a permanent agriculture, that these fundamental soil differences must form the basis for any proposed plan of management.

It is evident that the agricultural utilization of muck is a distinct agricultural problem and demands solution from the unique point of view which the facts present. In short, the maintenance, or increase of organic matter and nitrogen is the basis for scientific farm management of upland soils. In muck there is an abundance of organic matter and nitrogen; manifestly, muck problems are different from those of upland farm management. The point of view and vision of muck problems cannot imitate empirically upland agriculture, but must seek out the basic truths underlying its own problems. The striking contrast of upland farm management and muck farm management reflects the difference in the soils dealt with. The farm management for upland soils seeks to conserve and hoard the scanty supply of organic matter and nitrogen, or to add to it. Efficient muck farm management is concerned with the most profitable means by which this nitrogen and organic matter may be utilized. The farm practices producing the ideal physical conditions of a muck soil, which the muck farmer by long experience has learned to recognize, but of which we have no standard measurements, remains but little touched by the scientific investigator.

The increasing doubts which soil students are expressing as to the value of chemical analyses in determining the value of highland soils may not apply to muck soils. Professor F. J. Alway, Minnesota, has indicated, based upon his peat experimental plats, that chemical analysis may be of great value. However, we contend that these analyses when used alone are not reliable as a measurement of the potentialities of the muck analyzed. Numerous examples of the inadequacy of the chemical test in the determination of the agricultural possibilities of muck have been brought to our attention. In understanding the limitations of chemical tests for muck soils, we have to deal with a significant distinction between upland and muck land farming. While it is true, rightly or wrongly, many specialists ignore the activities of soil organisms manifested in upland soils, with muck soils they are not to be so ignored.

The submergence of plant residues prevents decay. There

is produced an anaerobic condition in which these remains are preserved. In the complex anaerobic changes which take place, preservative substances are produced so that essentially these partially decayed plants have been "ensiled." The muck deposits are large silos in which organic matter has been "pickled." Then let us understand that we are dealing, not with a mineral system, but distinctly with a biological system. If organic matter represents potential energy in highland soils, how much more truly must this fact apply to muck soils with high organic matter content. The physical and chemical changes which take place in these deposits of organic matter are brought about to a large extent by micro-organisms. The measurement of these changes in relation to the microbiological activity concurrent with them is the means by which standard measurement of muck soils will be evolved.

A study of muck soils presumes the dynamic point of view—the understanding that these soils are continually changing. The fibrous, loose, toxic, infertile swamp of this year may be the compact, finely divided muck three years hence.

It is obvious that muck problems are the problems essentially of the botanist and bacteriologist; the botanist to study the plant types—their classification, ecology and distribution, and the bacteriologist to investigate the changes which take place while the plant remains are being deposited and the changes which go on after the swamp is drained and cultivation is begun.

When research proceeds along these lines and is correlated with those dealing with physical and chemical measurements, the fundamental studies of the muck problems will be under way. We must be able to measure not only in terms of chemical analysis which measure total chemical constituents, but in the terms of chemical changes, the simplification of the organic matter. The changes in water holding capacity, absorption, granulation, heat conductivity, collodial properties, etc., should be determined and their measurements standardized. Until we have a better knowledge of the chemical, physical and biological phenomena correlated with the various stages of swamp reclamation, we will always be "guessing."

At present, chemical analysis supplemented with observation of the natural vegetation is the basis upon which recommendations must be made. In developing areas, crop test plants should be carried out on a fairly large scale before the major project is developed. The natural vegetation and subsoil are now used almost exclusively by most farmers who are prospecting concerning muck reclamation.

It may be interesting to note some observations of practical muck farmers in this regard. Farmers claim muck underlaid with clay or marl is of better quality than muck underlaid with sand. Muck through which streams are passing, or ditches reveal water with high lime content, "hard water," have good possibilities. For example, muck which contains hard water springs is likely to be of good quality. Muck in which the water of ditches has low lime content, "soft water," is rejected as being of no argicultural value. Huckleberries, cranberries, thrive on this type of marsh and are indicators of muck of poor quality. While these observations have not been checked sufficiently to make a definite statement, it has been noted sufficiently to point out the possibility of such correlation. Very often one hears the statement that muck upon which hardwood thrives, is better than muck upon which tamaracks, cedars and spruces are found. Exceptions, however, are numerous to this view. The degree of natural drainage seems to determine the tree vegetation. Ash, elm and maple, follow tamarack, spruce and cedar, as the vegetation is built up above the water table. The writer has checked these empirical statements time and again in Michigan muck areas. The statements are borne out by numerous successful muck farm areas, and are more strikingly confirmed by many failures in muck land reclamation. The investigator interested in muck development has as valuable points of departure, the experience of years which slowly and at heavy cost, the pioneer muck farmers have accumulated.

As an example of the value of this accumulated experience, we may consider the problem of drainage.

Drainage.

A frequent question is "How shall I drain muck; where should I put the tile?" This is as general as the question, "How shall I drain my highland?" The matter of drainage which is concerned with removal of surface water in reclamation of swamps is obviously to be differentiated from the subsoil or permanent drainage project which follows. In an appraisal of the muck drainage problem the different types of muck must be considered, not only as to physical properties, but as to variations in subsoil and relative instability as compared with highland.

The drainage plan must look beyond the first few years when the changes will be rapid, and wait until the muck settles and becomes comparatively stable. Experience indicates that it is not a good practice to tile immediately after

the surface water is removed. It has been found advisable to drain by main open ditches and, after several years to tile to these mains. The types of muck vary to such an extent that it is not safe to advise the distance between and the depth of, drains without qualifying the type of muck concerned.

For example, the conditions of a large tract may be noted in which the main drainage ditches are a quarter mile apart, and the texture of the muck such that it was necessary after several years, to place dams in these ditches to prevent too rapid drying out of the soil. On the contrary, in the Kalamazoo section, ditches are frequently two rods apart, and three feet deep. The growers are troubled with excess water in wet seasons. Below the top twelve inches of well decomposed black muck, there is an almost impervious layer of compact red fibrous sedge formation which furnishes a splendid irrigation system in dry times, but is a nuisance in wet periods.

The Phenomenon of Nitrification as Applied to Muck Agriculture.

Along with utilizing the experience of the successful practice, muck land management requires the rational application of known facts of soil bacteriology. Probably no phase of soil science has received so much attention in recent years as the microbiological process by which nitrogen is made available for plant use. It has been pointed out that muck soils are abundant in nitrogen. A brief discussion of the process of nitrification and the observations pertinent to this phenomenon as related to muck farm management is essential.

Nitrification is the most significant and basic process underlying the farming of muck soils. The relation of microorganisms to the relatively small quantity of organic matter in an upland soil has been shown to be of great practical importance. The importance of micro-organisms to the practical utilization of muck soils with this high organic content may safely be inferred in the light of these investigations. That nitrification, the conversion and simplification and oxidation of complex organic compounds by soil bacteria, is the means by which nitrogen is made available for use in muck soils, is an established fact. That the muck soils which have been cultivated contain large numbers of nitrogen-fixation bacteria has been verified by the Department of Bacteriology, Michigan Agricultural College. Numerous observations have indicated that the matter of fertilization of muck land has an effect upon the micro-organisms of the soil and their activities, thus cor-

roborating recent investigation of similar effects, produced by the use of fertilizers on highland.

Facts are already at hand to explain many of the phenomena which accompany the nitrogen cycle alluded to. Following the classic researches of Klebs which have recently attracted much attention as discussed by Kraus, we are recognizing the role that nitrogen plays in fruit production as well as in vegetative growth, lodging of stems and the filling of seeds, in fact, fructification itself, to be influenced by the process of nitrification.

The problem of handling muck crops becomes associated with field practices such as will accelerate or repress nitrification. Fertilization seems to be concerned with the problems of balancing the excess nitrogen with the proper quantities of minerals. The practical muck farmer must keep in mind that the factors of moisture and temperature, fertilization, tillage, while influencing the crop which is being grown, are also to be considered in their effects upon the micro-organisms which are the agents for the preparation of plant food materials.

The following observations are cited to show the fundamental and far-reaching results that are associated with the availability of nitrogen in muck, and the practical importance of properly developing conclusions from the facts.

If a quantity of manure is applied on muck and an equal amount of essential elements in the manure is applied to a similar area next to it in the form of mineral fertilizer, the celery crop upon which the manure has been applied without question makes a much greater growth.

A plant of onions was fertilized with 200 pounds of sodium nitrate, the other with 200 pounds of acid prosphate, with a check plat between them. An analysis of the soil indicated an adequate phosphorus content. It should be noted that onions are planted early in the spring. The nitrate and phosphate plots yielded about 450 bushels to the acre, while the check plat yielded 300 bushels.

It is entirely in accord with recent investigation to assume that the acid phosphate stimulated the development of the nitrifying bacteria which produced the same effect as the direct application of nitrate. It may be concluded that the phosphate was an indirect nitrogen fertilizer on muck. This most peculiar practice, by which substitution of acid phosphate for sodium nitrate, has been used repeatedly at my suggestion on onions and early celery with uniformly good results. In view of the well known fact that phosphates stimulate plant growth in the early stages of development, there

would undoubtedly be a direct effect upon the plant. This effect, however, does not fully explain the reaction because it is true that the application of acid prosphate will result in no such stimulation when applied on the same crop planted in the summer. Michigan celery farmers usually plow manure under in the spring. Is it not true that recent European investigations seem to recommend this practice? Does the manure warm the soil and the soil bacteria become active sooner?

It is suggested that the introduction of rotted manure in the spring promotes nitrification more rapidly than if the manure had been applied in the fall and plowed under, notwithstanding the loss by leaching and decomposition in the manure heap.

Onions grown on loose muck develop thick necks and scullions. Similar effects are noted with over-fertilization with nitrogen. The good grower has learned the relation of well-packed muck to a marketable crop. Rolling muck represses nitrification.

It is the general opinion that cauliflower cannot be grown on muck. However, when muck is well fertilized with phosphorus and potash and thoroughly rolled to prevent excessive nitrification, cauliflower can be grown successfully on muck. Thorough rolling and packing the muck is the limiting factor of success. Cauliflower is grown for the flower head. Excessive nitrification causes large leaf growth but no flower development.

Oats are drilled in on a corn stubble field, part of which was plowed, the remainder not plowed. The oats on the unplowed grew, headed out normally and produced ninety bushels to the acre. The oats on the plowed ground grew faster, taller, lodged, and did not fill. The lodging of grain may have been caused by the excess of nitrogen due to the excessive nitrification in the loose soil.

In 1914, a farmer in Allegan County planted navy beans on muck. Excessive vine growth and late flowering resulted in a crop failure. In 1915, two plats were planned, one-sixth of an acre each. The beans were planted six inches apart in the rows, and the rows 28 inches apart on one plat. On the second plat the beans were planted as close to each other as they could be drilled, two inches apart in the row and the rows 15 inches apart. On plat No. 1 there were no beans, only vines. On plat No. 2, blossoming began early, the beans ripened, and eight bushels were harvested on one-sixth of an acre. Yields like this are rare; these tests open up a wide range of possibilities.

Muck farmers have learned that the residues of crops have a significant effect on the following crop in so far that it is distinct for each crop residue. For example, mint following oats will be a better crop than mint following corn. The crop following millet seems to start more vigorously and show a healthier growth than the same crop after timothy or corn. These observations are particularly interesting in view of recent investigations on the relation of residues of microbiological activities to crop growth. These observations are given to indicate that the problem of muck fertilization is not so simple as fertilizer tests indicate. It is necessary to know that the soil is deficient in mineral and to add the required amounts, but it is also essential that the extent of nitrification be measured in terms of crop requirement. For example, from the viewpoint of the phenomenon of nitrification, a crop which is planted in the early summer presents a different problem from the same crop plated early in the spring. Early spring celery is a different crop than summer or late celery, from the viewpoint of nitrogen requirement. A crop grown for the flower such as cauliflower presents an entirely different condition from the biological view of fertilizer practice on muck, than cabbage. Excess seed may be planted to utilize the excess nitrogen and bring about a balanced crop growth. The soil is rolled to repress nitrification, stirred to promote nitrification. The suggestions which follow in the development of the farm management plan take this point of view into consideration.

Commercial Fertilizers.

In the previous examples the factors which influence the availability of nitrogen in muck, and the effects of the release of nitrogen too rapidly are seen to be of great practical importance. In considering that these effects are biological in their source, it has been shown that commercial fertilizers will naturally affect the micro-organisms and the nitrogen supply dependent upon their activities. Also, of course, commercial fertilizers will have a direct effect upon the plant growth, each exerting its selective influence as has been established and is well known. In general, it is assumed that nitrogen would not be applied except under special conditions, that potassium and phosphorus will be added in such mucks in which it is determined that these elements are deficient.

Two factors were concerned in a general recommendation of manure supplemented with acid phosphate for muck farmers.

1. The value of barnyard manure, far greater than an

estimate from the chemical elements which it contains.

2. The high price and scarcity of potash fertilizers and the comparatively large quantity of potash in manure. However, in consideration of the experience of farmers who had used potash, and noting the results of tests which have been carried out in the last few years, it may be said that the assumption that potash is the limiting factor on all Michigan mucks is not valid. It may be well, therefore, to consider the three essential elements individually.

The use of phosphoric acid in the form of acid phosphate has been found highly profitable under a variety of conditions. Two observations upon the seeming effect of acid phosphate upon nitrification have been noted: (1) Good results have been experienced on mucks with an adequate phosphoric acid content, indicated by analysis. (2) Results with acid phosphate are most apparent with crops which require early spring or late fall growth.

The potash needs of Michigan mucks may be classified as follows:

Shallow muck with clay or marl subsoil—potash not after cropping two or three years.

Deep muck underlaid with sand—potash needed immediately.

Shallow muck with sand subsoil—potash needed immediately.

Shallow muck with clay or marl subsoil—potash not needed.

Potash seems to be most essential in acid mucks.

The relation of potash in the filling of grain will be noted later under a discussion of grains on muck. Nitrogen fertilizers do not usually pay when applied in the summer. They are profitable on intensive crops in the spring and fall; and in the summers which are unusually cool and wet. The value of nitrogen fertilizers are lost when the spring is warm. Practices which will promote rapid and early nitrification will make the application of nitrogen carriers unnecessary. The value of lime as a soil amendment will be taken up later.

The application of sand and gravel on muck has given excellent results, but whether or not this is a profitable practice is still an open question in Michigan.

The whole problem of the proper use of commercial fertilizers, as well as the use of cultural methods which will have an effect on the utilization of the nitrogen in muck is no limited study to be discussed so summarily. The writer, in out-

lining the above suggestive facts, is calling to attention the meagre amount of experimental data, as well as contrasting the inadequacy of the present available upland recommendations. No phase of muck farm agriculture plays so important a role as this.

Still another line of endeavor must be mentioned which has bearing on the prompt development of the muck areas. The writer wishes to call attention to the need for plant breeding investigation as applied to muck agriculture.

Muck Crops and the Plant Breeder.

The possibilities for the plant breeder in the field of muck crops has not been recognized widely in this country. The results abroad should stimulate work here. It has generally been assumed that varieties that have been found adaptable to the highland can be used on muck. This is a serious misapprehension. There is no substantial reason for assuming that the varieties adapted to the upland mineral soils can be used on muck with success. Several examples may be mentioned. The grain problem in relation to muck farm management will be discussed later. It is enough to note at this point that, considering the average of ten years, the majority of muck farmers who are successful, do not favor growing any grain. The risk is too great. The difficulties are lodging and delayed ripening. A test with oats was carried on this year on the Woodward farm at Constantine. Varieties of oats recommended by the College were planted. These varieties had achieved an excellent reputation on the various types of soils in Michigan, some on heavy, others on light lands. When the experiment was planned, it was suggested by Mr. R. Zimmerman, the farm manager, that Illinois Red and Iowa "60-day" oats be added to the plant. Both of these varieties proved their superiority on muck. They had shorter straw, matured earlier and were able to be harvested while the other varieties under various treatments and with various rates of seeding were a failure. Subsequently it was revealed that the Illinois Red variety had already been found to be adapted to the muck in this section after many years of trial of numerous varieties. While in determination and selection of varieties for our uplands we strive for better yield or resistance to disease, it should be emphasized, that as far as the muck problem is concerned, it is plainly a question of finding a type of plant which will grow so that it will mature normally. The yield is a secondary factor in the present status of the problem. The ideal plant for the muck farmer is one

which will grow a short straw and mature seed quickly. In a similar manner the entire grain problem may be scrutinized. There are years when the small grains do very well on muck —spring wheat, winter wheat, rye, winter and spring barley. It is a question of the soil and climate. It is a question of the proper varieties. As far as has been brought to our attention, there is nothing being done in the United States on this important phase of making our muck land of permanent agricultural value.

Similarity, the question of successful corn culture on our muck lands must be studied; corn for grain and corn for silo. Silage is one of the important factors in the proposed farm management system. The upland short season varieties are not adapted to our muck lands. Varieties which have been recommended by various stations have been tried. At present, co-operating with successful muck farmers in Michigan, selections have been made of several types of corn which seem promising. The significant point to be made is this: When these varieties were grown on upland, they were not found to be desirable, grew very short, and were of little value.

One example in the vegetable field should be mentioned. It is a fact that many of the best varieties of celery on the upland are among the poorest for the muck.

One cannot pass the genetic problems without pointing out the field of frost resistance and its relation to the muck problem. This is exceedingly important because the danger of frost to muck crops is always to be considered.

Frost in Relation to Muck Agriculture.

By virtue of the relation of water to muck formation, muck areas are most frequently formed in the areas of the lowest altitudes.* Muck is formed in these pockets into which the cold air drains. Consequently muck areas suffer from frost when the surrounding upland escapes. This is a limiting factor which must be considered in the development of a plan for muck farm management.

It may be well to note the observation of farmers as to frost: A well-compacted muck will not frost so quickly as a loose muck. A frost is feared after a prolonged drought. When the soil is dry the frost damages seems more severe than when the soil is moist. Frost causes greater damage on the crop which is most recently cultivated.

*Note: The exception is quite common in Michigan. Where springs are common, muck may be formed on the slopes of hills, Grand Traverse County, Michigan.

Summary.

The purpose of this introduction is to emphasize the importance of looking at the entire muck question from the muck farmer's point of view. He has an entirely separate agricultural problem. The agricultural bulletins which have to do with farm practice as it pertains to soil handling, or as it refers to farm crops, are difficult to apply and often mislead him. Consequently, efforts toward the establishment of peat experimental stations which shall give their entire time to these problems should be endorsed. The creation of such an experiment station has been recommended by the Michigan Muck Farmers' Association.

Muck farm management divides itself into two main phases; as applied to intensive and to extensive muck farming.

Muck Farm Management Applied to Intensive Farms.

Intensive muck farming is carried on in southern and western Michigan, in the vicinity of Kalamazoo, Decatur, Niles, Dorr, Byron Center, Holland, Zeeland, Hudsonville, Grand Haven, and Muskegon. The salient features of intensive muck areas may be mentioned briefly:

These areas are in vegetable culture, varying from one to fifty acres in vegetables under a unit farm management. Celery and onions are the main crops. A large increase in the past three years of lettuce and cabbage is evident.

There is nothing particularly exceptional about the high-priced intensive areas as differing from other low-priced muck areas, subject to same climatic conditions, and proximity to transportation facilities. The high price is due to a large extent to the clannishness of the Hollander folk who farm these lands. Seven hundred dollars an acre for muck is not exceptional if it is in a community near a church and school, although it may be exactly similar to muck ten miles away, offered for one hundred dollars an acre.

Within the last few years the fertilizer problem has become a serious one. Previously barnyard manure had been readily procurable from Chicago stock yards. Now it is no longer available at the previously profitable rate. On the farms which have utilized large quantities of manure the use of acid phosphate has paid well. Where commercial fertilizers

had been used the high price of potash is a matter which has to be solved by Congress.*

The intensive farmer has learned that nitrogen fertilizers only pay when applied in the spring and fall. That is, when nitrification is not active, nitrogen may be supplied by fertilizers. The possibilities of stimulating nitrogen formation by the use of acid phosphate has been noted. A practice which several intensive farmers have adopted is worthy of attention. It was noted that muck which contains celery and cabbage trimmings when allowed to remain in a heap, had a fertilizing value on muck which could not be attributed to the constituents in the plant residues. It was assumed that the value came from nitrogen of the muck made available in the heap. This suggested the possibility of composting for the purpose of making nitrogen available for early crops. It was tried out sufficiently to note the process. The results were highly satisfactory. The general suggestion made is as follows: Muck is mixed liberally with stable manure, the amount of muck used gradually decreasing as the time for application to the field approaches. If it is planned to apply acid phosphate the following spring, acid phosphate is added to the compost heap. It is evident that should the value of this practice be established, the muck farmer would be able to manufacture his own nitrogen fertilizer for early and late crops or for use in such cool seasons in which nitrification in the soil is not active, and available nitrogen is essential.

It is evident that special olericultural investigation should be carried on in the vegetable field as it applies to muck. Studies should be initiated on the question of varieties, culture, harvesting, and new crops which may be grown on muck.

The possibilities of the canning factory in connection with intensive muck crops have hardly been recognized. Sweet corn, cabbage, pickling onions, celery, spinach, beets, peas, beans, cauliflower, etc., can be grown in quantity. As a muck project for 1920, work is being planned such as will bring the canning industry in touch with these intensive muck sections; also as related to these same crops when grown as a cash crop in the extensive plan of management.

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*Note: The muck farmer cannot afford to pay for protection of the potash industries which were initiated during the war. It will be necessary for the country at large to assume the protection of these industries or to allow the importation of French potash. The fact remains that the muck farmer cannot pay the price per unit at which potash is quoted at present.

Management of Extensive Muck Farming.

A discussion of this most important phase of the agricultural utilization of the muck lands may be introduced by stating that a very small percentage of the muck lands of Michigan, Minnesota, New York, Wisconsin, and Indiana, would produce all the celery, onions and lettuce and cabbage for the United States for the next hundred years.

The mistakes should not be made of judging the muck lands of the United States from the viewpoint of vegetable production. Similarly, at this point it may be well to note that the mint industry, which is an important muck crop in Michigan and Indiana, is a specialized one. It is estimated that a vigorous campaign, pointing out the profits which have been made this year in mint oil, would result in the production of a sufficient number of pounds of mint to break the mint market to below the profitable basis next year. Hence we are not urging an increasing mint production. The increase will come without persuasion and the result is certain to be disastrous for the small grower, if not next year, the following year. At that time, those speculators, jobbers or growers who can, will store mint and buy at the low price, disposing when the market rises.

The large part of the muck lands of the United States must be developed by general farming, and it is upon this question our thought should be focused. What is offered as a permanent system of general farming to the prospective food producer which will be profitable? Muck land will make good pasture. Here is at least a start. All farmers are agreed that muck land that will grow blue grass is good pasture. It is earlier than upland pasture and will last longer, provided the moisture is present. The experience of our muck farmers shows that it makes good hay land. Further observation verifies that corn makes a very satisfactory crop if the frost is delayed. The consensus of opinion of the muck farmers is that part of an acreage may be put into grain, but considering a ten-year average, small grains are not dependable. Observation and correlation of paying practices has resulted in making the following general recommendations to the prospective muck farmer in Michigan, as a complete system of muck farm management; cattle, dairy or beef; ensilage and hay for feed; hay and sugar beets as cash crops; with grain or vegetables as additional possibilities.*

1Note: A discussion of livestock in relation to muck agriculture is omitted because the handling of stock on muck does not present any serious problems which are distinctly different from upland practice. The growing of feed involves factors which are peculiar to muck agriculture. These are to be taken up briefly.

Cattle.

The discussion of the livestock will be omitted except to note that for beef the Hereford is favored, while no special dairy type is preferred. A discussion of the farm crops for feed involves a discussion of muck crops to be considered briefly.

Silage.

To attempt to raise corn for grain on muck lands, even in the latitude of southern Michigan, is an exceedingly speculative procedure. To raise corn on muck for the silo is a relatively safe practice. The difficulty is that the corn remains green and the formation of ears is rather the exception than the rule. This does not give a high quality silage. The planting of soy beans in corn was suggested in 1918, when southern Michigan experienced a frost on June 22, which killed the corn above the ground. Previous successful experience on small plats warranted the recommendation. The results were much better than was anticipated. The corn recovered and made a fair growth, but the soy beans grew so profusely that the quantity of silage was greatly increased and the quality much better than it had been in previous years. This test on the Beebe farm at Niles, Michigan, resulted in the general recommendation of the use of the soy bean for the muck farmer in that section. This year it has also been a decided success as a hay, some reporting five tons of dried hay to the acre. During 1919, corn planted on muck, interplanted with soy beans, made highly satisfactory growth in all sections of southern Michigan. The question of variety arises as with other muck crops. The Ito San grows much larger on muck than on high land, and often the pods fill. Growers have been urged to make selections in corn, and it is hoped that strains of early maturing corn, especially adapted for muck, will be developed.

The second possibility for silage which is still in the experimental stage, but which should receive careful consideration, is the sunflower interplanted with soy beans. The important feature of the sunflower is that it is hardy to frost. The sunflower makes such a large growth on some of our fertile muck areas as to make it out of the question to allow it to go to maturity. The sunflower, planted late, sown thickly, interplanted with soy beans and harvested early, may be a solution of the silage problem on muck.

The third possibility which has not received sufficient trial, is oats and peas. They grow profusely on muck and

make a good quality of silage. Canada field peas are hardy and do not frost easily.

Hay and Pasture.

Alsike and timothy are the standard combination, probably because they are wet land crops and are hardy. The possibilities of investigation have been indicated to the American Peat Society by noting the different combinations and the data accumulated concerning them by Professor Arny in the peat experimental work in Minnesota.

This has been an especially dry year in southwestern Michigan. In a test on deep muck with marl subsoil, alsike seeded alone, died from the effects of continued drought, while sweet clover grew vigorously. This will be watched to note the effects of this winter.

The relation of lime to clover seeding may be touched upon at this point. On the well-decomposed mucks in southern Michigan, or part of lower Michigan, the use of lime has been shown no benefit. A carload was distributed in the Kalamazoo region and no results were evident. However, lime applied on muck lands which are not well decomposed and which show a distinctive acid reaction, especially where the subsoil is sand, is undoubtedly essential. An important observation in this relation should be noted. The tests of muck areas by the standard methods to indicate lime requirements are not only of no value as an indicator as to treatment, but many times were of actual harm in giving a wrong impression of the potentialities of the area in question.

New muck which has not been drained will show an acidity which would indicate the necessity of many tons of lime to the acre. When this muck is drained, cultivated and especially when manure is applied and decomposition hastened, the soil will indicate a very much lower lime requirement, while the subsoil, that is, the muck which lies below the decomposed muck, may show a highly acid reaction.

Here is a case in point: A prospective buyer of a muck farm was advised that he needed fifteen tons of lime to neutralize the acidity of the muck and that it would not pay. Another farmer who was not acquainted with their recommendation applied barnyard manure in liberal quantities with excellent results and complete removal of acidity. Of course the application of manure would tend to reduce acidity, but it seems that we cannot neglect the fact that muck or organic matter, not only contains, but develops basic material bound up in a manner which lime requirement test would not show,

and which only chemical analysis will show. When once this organic matter begins to decay, would not this basic material have an effect on the soil acidity?

Observation has not indicated the value of lime as a limiting factor in obtaining seedings of alsike and timothy on muck. It should be noted that these are acid-tolerant crops. The limiting factor seems to be moisture. On a well-rolled, properly-prepared seed bed, no trouble is experienced in getting a seeding of alsike and timothy. There are several practical considerations which may be of value. Seeding with oats in the spring is not a good practice, usually because the oats grow so rank that the seeding is smothered out. The best plan is to seed on the stubble, after rolling and a shallow disking. Grass seed may be sown any time between June 15 and August 15, no earlier, because the frost very often injures the young seeding; no later, because the excessive thawing and freezing will kill a seeding which is not well established. Rolling in the fall is a good practice. Rolling the young seeding in the spring is an essential practice.

Pasture.

June grass will gradually come in on the hay field, and thus a good pasture may be obtained. The writer has no data on permanent pasture mixtures for muck lands. It may be well to state that the Federal Farm Loan Board has accepted the suggestion that the value of muck lands in southern Michigan be based on their grass value. This was placed at fifty dollars an acre and is conservative. Experienced farmers state that muck land which will grow good June grass can be safely valued at one hundred dollars an acre, considering present beef prices.

Muck land pasture is better than high land pasture, because it is earlier in spring and later in the fall than pasture on high land. Observations indicate that it adds at least six weeks to pasture value in southern Michigan. It will not suffer from drought when the high lands are burning up. A word of caution at this point: Cattle should not be pastured too early in the year on young seedings. The muck is likely to be too soft.

The value of pasture in that the muck is compacted by the animals should be noted.

The possibilities of research in developing some of our native grasses for our muck lands may be indicated. One need only note the growth of some of these plants and to make analyses of their feeding value to appreciate their superiority

to timothy or redtop. For example, we have "blue joint" (calamagrostis canadensis) growing hardy and rank, and relished as a forage. There are other possibilities which have not been exploited. Just as "blue joint" makes a poor showing on highland and is splendidly adapted to the muck, may it not be true that the grasses which have been developed for the highlands are limited in their value in these entirely different conditions in muck?

Fertilizing pastures may be found to be a valuable practice. Limited experimentation indicates profitable results.

Cash Crops.

The consideration of hay as a cash crop on muck is urged. Again a fundamental problem of management must be considered. To sell hay may not be good policy on the high land, but it is good policy on the muck. The muck farmer certainly can sell hay because he can sell organic matter and nitrogen without depleting the soil. The plan of the muck farmer should be to turn all the nitrogen and organic matter which he can produce as cash crops or beef, into dollars. The consumer pays high for nitrogen and organic matter, the elements of which the muck farmer has an excess. Consequently, he should plan to sell this excess and buy the mineral to replace the deficiency which exists or will exist in muck sooner or later.

Green manuring muck soils should be considered briefly. It is obviously unnecessary to plow under organic matter or legumes for the nitrogen and organic matter they contain. The practice of plowing under green crops on muck is practiced for its microbiological value. The rapid decomposition has the effect of composting, or of communicating decomposition to the muck and stimulating nitrification. Growers have found that beet tops, cabbage leaves, celery trimmings, or any of the plant remains plowed under, have a value on muck which cannot be accounted for, except in biological terms.

Grains.

The small grains are risky, as has been mentioned above. The reasons for this have also been touched upon. Oats, spring barley, rye, winter barley, wheat, are given in the order of the best prospect for success.

Based on experimental evidence from work carried on in various parts of the southern part of Michigan, the following recommendations for grain culture are made:

1. Heavy seeding; at least $1\frac{1}{2}$ times the amount of seed that the high land farmers use in the vicinity.
2. Applying acid phosphate or potash or both.
3. Thoroughly rolling the seed bed.

The heavier seeding is an important factor. For example, if oats are seeded less than three bushels to the acre, the yield will be less, and the weeds will grow more profusely, leaving the soil in an undesirable condition. The excess seeding also has the tendency to crowd the plants and hasten ripening.

The reason for the urgent recommendation of the use of acid phosphate is this: Not a single instance has been noted in which it has not helped the grain crop, even where soil shows an adequate quantity of phosphorus.

The relation of potash to the filling of grain cannot be over-emphasized. A definite observation may be noted. Several fields of wheat were observed in which proper handling has resulted in what seemed to be an excellent stand of normal wheat. The straw and heads, externally, grew well, but upon more careful examination the kernels were found to be shrunken and valueless. Significantly, wherever the clay subsoil was thrown out on ditch banks, or where the adjoining high land was mixed with the muck on the edge of the swamp, the heads filled normally with healthy grain. In the following year, where potash was applied the grain was a good crop, but where potash was omitted, the failure was repeated.

The importance of rolling has been referred to above. It seems to repress excessive nitrification and prevents lodging. Normally subsequent application of potash corrected this serious condition.

The use of buckwheat and millet are considered important muck crops, in subduing the sod. It cannot be said that those are profitable as a regular part in the rotation.

Beets.

It is believed that the sugar beet is the crop which is to place the muck lands of the North Central States in a place of the highest importance. Some of the best beet fields of Michigan in the Saginaw Valley are on muck soil.

The place of the sugar beets in the muck-farm management plan is emphasized: Beets are to a great degree, frost proof except when the plants are just coming up. They are a staple crop. There is very little possibility of over-production. The tops and pulp can be used as feed. The fact that the sugar beet factory usually aids in handling the crop,

particularly as far as labor is concerned, is an important point in the favor of the beet.

The manufacturing of beet sugar is a standardized agricultural industry. No crop will pay more for careful attention. The limiting factors in the growing of beets on muck have to do with preparation of the soil, especially when the muck is new, or not well decomposed.

Beets should not be the first crop on muck, which is fibrous and loose. It is best to grow a cultivated crop, such as corn, following with hay and pasture, then with another cultivated crop before beets are attempted.

Rolling is the most important single operation in the handling of muck for beets. I have seen a fair crop of beets on new and undecomposed muck, but which had been thoroughly rolled with a tractor; on the other hand, I have seen failure, where the muck was loose and not rolled. The procedure should be: Plow in the fall, roll, disk lightly and roll again; in the spring, disk and roll again, as beets require a firm seed bed. Some of the best growers favor spring plowing, with light application of manure disked in.

The use of acid phosphate is especially to be recommended for beets on muck. In general, when the rotation on muck is established, it is planned to follow the corn with beets. The farm manure applied to the corn leaves the muck in excellent condition. An application of acid phosphate at this point is particularly profitable. It is to be noted that acid phosphate gives evidence of a peculiarly stimulating influence as was mentioned previously in connection with onions. The acid phosphate application causes a quick start and a rapid early growth.

The matter of fertilizing the sugar beet grown on muck is concerned with a number of factors which can merely be outlined in this paper.

When beets are grown on muck, in the same manner as grown on high land, assuming that the muck is thoroughly rolled and well prepared, it is essential to point out that an increase in tonnage and sugar percentage may be obtained by crowding the plants, so that a smaller beet is produced. This is a factor in high sugar content which should be noted.

The effect of potash on sugar beets in the production of sugar has been experimentally proved. It has been shown that even with a large leaf surface, sugar will not form without an adequate supply of potash. This is an important fact which the beet grower on muck must keep in mind. It is

essential that the quality of the beets be kept up so that there should be no occasion for discounting muck beets.

Sugar beets of high quality, and high tonnage, can be grown on muck if the crop is properly handled.

The wind is a serious factor to contend with in growing sugar beets on muck, usually causing serious injury in the spring, during planting or when the seed is germinating. The use of proper implements and the planting of temporary windbreaks have been used successfully in protection from wind injury. The corrugated type of roller is a valuable implement for the muck farmer, especially in relation to wind protection. Rolling before and after planting ridges the soil in a manner which makes a very efficient windbreak. The use of strips of rye planted the previous fall, planted four rods apart on large fields has afforded good wind protection on large muck areas.

Feeding Root Crops.

The value of root crops for feeding is not sufficiently recognized by the muck farmer. Mangels, turnips, beets, carrots, make a large tonnage and are valuable. For example, among the interesting rations which necessity has forced muck farmers to work out, there is the common use of carrots and millet hay for horses as a winter working ration.

Intensive Crops as Cash Crops.

The place for intensive crops in the extensive system must be noted. It is obvious that onions and celery, carrots, cabbage, lettuce, peas, etc., may be grown as cash crops on small acreages in connection with the extensive plan. The important factor is the matter of disposition and distribution. The canning factory in the vicinity of these muck areas would use cabbage, pickling onions, spinach, sweet corn, peas, cauliflower, etc. With proper means of distribution small quantities of onions, celery, cabbage, lettuce, carrots, beets, turnips, etc., can be gathered in car lots and sold.

Hints on Swamp Reclamation.

It is evident to the student of swamp land problems that no outlines of the practical aspects of muck soil reclamation is complete without a brief discussion of clearing and subduing the virgin soil.

While timbered muck may seem more difficult to clear because of the appearance of the luxuriant growth of the brush and trees, it will be found that the trees are shallow

rooted. Moreover, muck, comparatively loose and not settled, will lend to the ease with which clearing may be carried out. A method which has been used and which strikingly takes advantage of these facts is the use of the tractor for uprooting trees with chains properly placed.

Clearing of muck is quite distinct from the problems of clearing upland.

In subduing timbered muck, one is faced with a difficulty in plowing which is much more serious than the similar situation on upland. Under the surface of timbered muck, limbs and roots of trees and shrubs which have died and have been submerged, will cause difficulty. A single disk riding plow with three good horses will handle the first plowing. It will be necessary to remove the larger roots or limbs. For several years, limbs and roots will cause trouble. In fact, as the muck settles, a good-sized wood pile will be taken from an acre each year for several years.

While these difficulties are not present in the breaking up of the so-called "prairie marsh" muck which is not timbered, there are several practical facts which may well be noted. This type of marsh in which the sedges predominate is difficult to plow. Considering the ordinary farmer with no tractor, the plowing should be shallow at first. The "fin" Coulter type of plow has been found ideal for this purpose. It has the advantage of the long mould board which most plows especially adapted to muck have, but in addition it has the coulter attached to the plow point at right angles to it, all in one piece. It is made on the principle of the "slane," which is used to cut out blocks of peat for fuel. It eliminates clogging between the beam and the coulter, and the plow point and the coulter, which is the objection to other types of plows. The first plowing is usually found very difficult. The sedge roots are so tenacious and the muck so soft that they will accumulate on the edge of the sharpest plow point with the result that the plow is thrown out. It is evident that in the plowing of this type of muck that the point and coulter must be kept sharp. It is found advisable to sharpen or change points two or three times a day to do the work efficiently on some types of prairie muck. The first plowing is shallow because it is essential that the draft be as light as possible, and the footing for the horses secure. It is found that the horses mire easily; in many instances it is common to use especially adapted muck shoes for horses on the first plowing. Once the three or four inches of sod is turned over, the muck must be continually worked until seeding. A crop such as buckwheat,

or millet, is planted which will subdue the sod. The next plowing is deeper and completes the disintegration of the sod.

The tractor minimizes these difficulties. The caterpillar type of tractor is the type which is best adapted to working muck land. There is very little wear from grinding as far as the muck is concerned. This fact and the point that the vibration is taken up to a great extent by the muck, are important considerations in estimating the life of a tractor when used on muck as compared to the same tractor used on clay or sand. The caterpillar tractors will plow where horses will mire, and in breaking up large tracts there can be no question as to their superiority and efficiency. There is no difference of opinion among muck farmers on this matter. However, the question as to whether the tractor is profitable on the muck farm, which is under cultivation, is by no means settled.

It should be noted that dynamite works very efficiently in clearing muck, presumably because of the well-known effectiveness of dynamite in a saturated soil. Temporary ditches can be made easily for removing surface water in order to facilitate reclamation by the use of dynamite.

The question of burning over muck to clear it rapidly, the value of burning over to provide lime and stimulate bacterial activity, and a consideration of the numerous auxiliary factors concerned, are matters upon which there is a wide difference of opinion. It is a subject which deserves lengthy discussion and which is closely bound up with the practical question of reclamation. No opinion is ventured because of the insufficiency of data. It is desired merely to point out at this time that burning over is practiced and that there are many men who favor this as a method of rapid clearing.

It is obvious that the question of reclamation of swamp lands is a large problem, some of the phases of which have merely been mentioned with the hope of stimulating investigation rather than giving authoritative information. The owners of large tracts or small tracts of swamp know that it is the initial cost of getting the swamp in shape for cultivation that will determine the success of the project. At first it seemed that each project was a distinct problem in itself, but numerous observations indicated that there are many places which these projects have in common, which will, if properly correlated, prevent numerous failures and disappointments for future prospectors.

There are a few significant facts that those who are inter-

ested in the swamp land reclamation in the United States ought to recognize:

(1) In every phase of the muck problem, beginning with the survey for drainage, to the system of farm management, we cannot be governed by knowledge derived from experience with upland. The lack of the appreciation of this fact has caused so many disappointments, from the small two-acre intensive farm to the fifteen-thousand-acre ranch, that particular emphasis is warranted.

(2) Before submitting a program for the reclamation of these areas and urging their settlement and cultivation, there are numerous fundamental researches which must be carried out which recognize the basic facts differentiating swamp land agriculture from upland agriculture. Peat experiment stations should be established similar to those which have carried on such splendid work in European countries.

(3) The experience of farmers who have been successful must not be ignored. Until we have made the investigations which are urgent, the practices of the successful muck farmers should be noted and utilized in directing the prospective reclamation project. Farm management studies of this type by competent observers would not only be of great value at present as a guide for extension workers in their recommendations, but of distinct importance to future investigators of special muck problems.

PYRITES AND ITS TOXIC OXIDATION PRODUCTS IN PEAT SOILS.*

By Clayton O. Rost, Division of Soils, Agricultural Experiment Station, University of Minnesota.

A mineral very widely distributed in peat soils is iron sulphide which appears chiefly as pyrite, although it sometimes occurs as marcasite (white pyrites). It is formed in peat under the reducing influence of decaying plant residues when waters containing iron and sulphate of lime come into contact.[1] The pyrite itself, as it is insoluble in water, is not toxic, but when it comes into contact with the oxygen of the

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[1]Wollny, Ewald. Die Zersetzung der organischen Stoffe und die Humusbildungen. 1897. p.

air it is changed to iron sulphate (ferrous) and sulphuric acid, both of which are soluble in water, toxic to plants, and able to prevent the growth of all vegetation when present in large enough quantities.

As the sulphide is the original compound from which the two toxic substances are formed it is the amount of this, its distribution, and its relation to layers containing lime are of much interest. European investigators[2] have found that ordinarily it occurs most abundantly in the muck substratum but on the Minnesota peat bogs so far examined the maximum amount has been found in the peat layer immediately above the muck. The presence of the ferrous sulphate and sulphuric acid and the amounts of these will depend upon the extent of the sulphide which existing circumstances have permitted. The installation of a drainage system will tend to carry away these harmful substances, but this, at the same time, improves aeration and hastens the oxidation of the remaining sulphide so that under the influence of drainage alone they will not disappear until all the sulphide has been oxidized and time enough has elapsed for the resulting products to be leached out.

Both ferrous sulphate and sulphuric acid are rendered harmless when any form of agricultural lime, either the carbonate, oxide, or hydroxide, is mixed with the layer containing them. There are instances, however, where these substances are present at the bottom of a bog in which the peat at the surface and for some distance downward is well supplied with lime, while in the subsoil a few inches below there is an abundance of carbonate of lime.

In connection with the reclamation of a bog the presence of such a toxic layer becomes of importance since, in the first place, if the peat is shallow, it may prevent the penetration of plant roots into the underlying mineral soil which otherwise might provide for any deficiencies in potash and phosphate. In the second place material from such a toxic layer thrown up in ditching and spread over adjacent land with the intention of improving it might prove injurious or if allowed to remain as a waste bank along the ditch would be unproductive. If the land being reclaimed consists entirely of deep peat the presence of a toxic layer will be of importance only in connection with the disposition of the material thrown up in ditching.

Accordingly, it is important that all tracts being considered for reclamation should be examined for sulphide and its toxic oxidation products. If present, the relative amounts

[2]Ramann, E. Bodenkunde. 1911.

of these and their distribution should be determined. The mineral substratum should also be tested for carbonate since, if it contains this, it may be mixed with the toxic material and the toxicity thus destroyed.

The occurrence of these three substances in Minnesota bogs has not been sufficiently investigated to know how extensively they occur, but representative areas of shallow peat in both the northeastern and northwestern parts of the state have been examined.[1] On an area five miles wide and fifteen miles long, in the vicinity of Meadowlands, in the northeastern part of the state, only one place was found where there was any sulphide. The peat at this place was deeper than in the majority of places tested, it being $3\frac{3}{4}$ feet to the muck layer, while the muck layer was of the unusual thickness of 12 to 15 inches. The exposure along the freshly dug ditch from which samples were taken showed this to be a small "pocket" approximately 300 feet in diameter in which there was a greater depth of muck. The sulphide was most abundant in the uppermost portion of the muck layer, but samples taken nearby and outside of the pocket showed an absence of this in both the peat and the muck. In all other places tested in this district sulphide was entirely lacking or present in only so small an amount as to be of no consequence.

The area examined in the northwestern part of the state extended from Golden Valley eastward some six miles. A thorough search for sulphides and the two toxic substances was made in the peat on the Golden Valley Peat Experimental Fields. In this locality sulphides are everywhere in the lowermost portion of the peat layer, but in only comparatively limited quantities.

Tests showed that only a few feet back from the banks of the drainage ditches oxidation, with the consequent formation of ferrous sulphate and sulphuric acid, had not progressed far enough to be of any serious consequence.

In some excavations on properly fertilized plots the live plant roots of crop plants were found penetrating through the lowermost peat layer, the muck layer and some distance into the deeper subsoil. So it is only in connection with material thrown up in ditching that the oxidation of the sulphide might be rapid and extensive enough to produce a sufficient amount of ferrous sulphate and sulphuric acid to be injurious to growing plants. However, even then this material is in practice unavoidably mixed with the highly calcareous mineral substratum so that any toxic substances formed would quickly be neutralized.

In areas of shallow peat east of Thief River Falls and near Goodridge, conditions similar to those at Golden Valley were found. The number of samples responding to the test for sulphides in the two portions of the state examined are shown in Table 1.

Samples to be tested for sulphide must either be examined very shortly after they have been taken from the field as any considerable lapse of time while the samples are in a moist condition will permit the oxidation of the sulphide, with the result that a calcareous peat carrying pyrite might show a strongly acid reaction indicating a toxic layer when in reality there was none.

TABLE I.

Number of Samples Showing the Presence of Sulphides.

Area	Number of samples collected.	Number of samples showing presence of sulphide. Peat*	Muck
	1. Golden Valley.		
1	6	6	4
2	13	13	11
3	5	5	4
4	6	6	5
Total	30	30	24
	2. Thief River Falls.		
1	4	4	4
	3. Meadowlands.		
1	6	0	0
2	8	0	0
3	4	1	1
Total	18	1	1

*The six-inch section immediately above the muck layer.

THE FEN COUNTRY OF ENGLAND.*

By G. R. McDole, Division of Soils, Agricultural Experiment Station, University of Minnesota.

(Read at the Annual Meeting, Minneapolis, Minn., Sept. 23, 1919.)

In the British Isles there is only one place where peat land has been successfully farmed on a large scale for any length of time and that is in the Fens or Fen Country, which lies around the Head of the Wash on the east coast of England. But little field experimental work or laboratory study has been given to these soils.

While at Rothamsted, in the early summer of 1919, I went by train to Brandon and spent some days tramping over the fields, examining the soil with an auger; also visiting with some of the largest and most successful farmers.

It is not my intention to weary you with a detailed description of the Fens, of which the written history dates back to the time when the Romans started the first reclamation work by building a sea wall which is still in service. I shall simply try to give you an idea of the district and draw some comparisons that may be of interest to us in this country:

As one travels from Cambridge to Norwich, after leaving Ely, he comes suddenly into the Fens. At first he might imagine that he was in Anoka in Minnesota, the broad, level topography reminding one of some of the large wire-grass bogs of that county. However, after a few miles things begin to look different. Such fields of grain have not yet been seen on the Anoka bogs, with the exception of our experimental plots on the Coon Creek fields. Soon the Ouse River is crossed and then you become aware that you are in a district entirely different from any to be found in Minnesota. Instead of the river being below the surface of the surrounding country, as we are accustomed to, the banks have been built up until it now resembles an irrigation canal built through a depression rather than a river.

Through the fields and along the road sides the ever-present drainage ditches are noticed, but at first one does not think of the river as the outlet for these.

From a very early day some of the high land, or islands, as they were in the Roman times, have been cultivated or

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grazed. Much of the land lies below mean tide level, necessitating protective dykes against the sea. However, do not think of this area as a former salt marsh which has been reclaimed. The remains of trees and other vegetation in the bogs indicate that it was originally an island-studded fresh water lake. No doubt its present low level is due to the gradual subsidence of the coast, probably connected with the formation of the English Channel and the separation of England and the Channel Islands from the mainland. There are, it is true, some salt marshes along the coast line that have been built up by the rivers depositing their sediment in shallow water, and many of these have been reclaimed and included in what is now known as the Fens, but their area is small compared with that of earlier origin.

The system of drainage employed consists in first deverting, by means of canals, the streams that had previously emptied into the area, so that they empty directly into the sea, thus protecting the lowlands from the flood waters coming from the surrounding high land. The streams flowing through the low land were straightened, their banks raised and their outlet provided with tide gates to prevent the incoming tides from overflowing the land. These tide gates are very ingenious in construction as well as simple in operation. As long as the water level in the river is higher than that of the sea the gates remain open, permitting the rivers to discharge into the sea, but as soon as the tide reaches the same level as the river the gates automatically close and remain shut until the tide goes out when they automatically open.

Formerly the rivers formed the chief means of transportation through the fen land. Since the coming of the railroads, water transportation has greatly fallen off, but there is now much talk of reviving it. However, they are making about the same progress in this direction as we observe on the upper Mississippi.

The country was divided into drainage districts, pumping plants installed and the water pumped from the land into the rivers. At first the pumps were worked by windmills—later steam engines were introduced and now in some of the later pumping stations internal combustion engines using gas supplied by producer gas plants are employed. In all cases coal and not peat is used as the real source of energy. It seemed rather strange that coal should be used to furnish the power to pump water from peat land considering the development of peat as a source of power through producer gas plants. I mentioned this to some of the engineers of the pumping plants, who gave no very satisfactory explanation as to why peat was

not used, but all expressed a very great preference for coal.

The first pumps were enormous scoop wheels from 24 to 36 feet in diameter. The Archamedian spiral has been tried with some success but has been displaced by high duty turbine pumps. The lift is comparatively small, in many cases only 4 to 5 feet, and the amount of water discharged per minute is enormous. Hence the cost per acre for the pumping is low, the heaviest tax being for the construction and maintenance of the canals and dykes.

The term "Fens" means nothing to us when we consider the soil. It is used as descriptive of a marshy area. In order to understand the soils of the district and the development of agriculture on them it is of course necessary to understand the conditions of their formation. There are three general classes of soil of agricultural importance covering the area, namely, glacial till. allurium, and peat. All the district is underlain by glacial debris, but this does not come to the surface in many places and so constitutes only a small portion of the tillable area. In many places the soil is sandy or gravelly, which accounts for the very low yields of grain obtained by the early Fen farmers, who farmed only those sandy and gravelly islands and the drained marsh at their borders. Before drainage these glacial "islands" were the place of abode of the early inhabitants of the Fens. Even to this day most of the houses are found on these high points, very few buildings being seen on the drained area, especially on the peat covered portions. The first soil to be cultivated was this glacial material; later the fen-men extended operations to the edges of these islands and out into the shallow peat.

As drainage proceeds it opened areas of alluvial deposits, some of which have soils probably among the richest in the world. It is on this soil that the first real agriculture of this district developed. Some of the lowest areas were filled in by a system known as "warping." The silt-laden streams were turned into these low spots, the silt allowed to settle and the water pumped back into the river. This process was repeated until in many cases the level was raised several feet, thus adding very valuable land. The process is slow and expensive and the land thus obtained difficult to bring into cultivation. It was no doubt renumerative in the days of cheap labor but it is not in use at the present time. The same may be true of the system of marling described below.

Next to the alluvial soil in extent and importance, and in many cases rivalling it in productivity, is the peat, of which two distinct types are recognized by the farmers of the dis-

trict, the one, underlain by clay, being considered of high agricultural value, while the other, underlain by sand, is regarded as very poor. An examination of the surface of the two types shows the former to be well decomposed and rich in mineral matter. Hence it may properly be considered a **muck**, whichever definition you prefer for this term. The other is poorly decomposed, distinctly fibrous in structure and poor in mineral matter. However, it is not so fibrous as to be difficult of cultivation. Occasionally sand appears mixed with the peat, giving rise to a powdery condition when dry that is conducive to blowing. Very little of this type is farmed with grain or cultivated crops and much of it in grass is not producing a profit.

Part of the difference in the development of the two types of peat may be attributed to the first being better drained and better insured against floods. Here, as everywhere on peat soils, the drainage problem is the first to be considered. However, the system of farming will account for some of the differences claimed or found by the farmers. From the earliest periods of which there is written history of agriculture in England there has been a system in vogue called "marling." The first marling was confined to the uplands by chalk. The process consisted of sinking wells or shafts to the chalk stratum, bringing the chalk to the surface and spreading it over the ground. No doubt the success of these early farmers had some influence upon the methods adopted in the Fens, where they follow much the same practices as the early Britons with modifications made necessary by different conditions. The clay subsoil underlying the peat contains considerable lime in the form of calcium carbonate, and is also quite high in potash.

Before the development of scientific agriculture, these farmers had found a method of meeting the natural deficiencies of the peat without knowing or realizing their chemical nature. The method originally employed in bringing it into cultivation consisted first in grubbing out the native vegetation, cutting off the hummocks and burning as soon as dry, the surface of the peat being lightly burned over or only charred. They found it was not necessary to burn the peat to ashes but that a mere charring was sufficient and equally effective. The ashes and charred peat were scattered, the surface worked up and cole seed or rape usually sown as the first crop. After cropping a few years the surface was again given a shallow burning and the ashes scattered before planting. This was accomplished by first paring to a depth of about 2 inches by a broadshare. This process, called "paring and burning", is still practiced, alternating with the marling. For

a time the process of paring and burning gave way to marling which was carried out much in the manner of the early Britons except that trenches instead of pits were dug, the clay thrown out and spread over the surface.

In some places these trenches served as ditches needed for additional drainage. In such cases the peat removed has been sold for fuel and clay used in making roads, leaving the trenches as open ditches. So in the sections cultivated for many years, no refuse is seen along the ditches. Some farmers improve their drainage by putting rocks or brush in these trenches, with a covering of turf and filling up with peat. Very few tile drains are used, the drainage being taken care of principally by the open ditches supplemented by the turf filled drains. One farmer in this part of the Fens informed me that the surface drainage was their only real problem.

In addition to marling a dressing of phosphatic fertilizer, either in the form of basic slag or superphosphates, is used, the former being the more common. I found no records of any general use of potash fertilizers, apparently a sufficient amount of potash being furnished by the clay of "marl", as it is called. The marling is repeated about once in eight years. Many make a light burning between the times of marling. The result of this method has changed the nature of the original peat until now, in many places, the soil at first doubtless a typical peat, is now really a muck. One result of this is that no very great differences are to be observed between the cultural and cropping methods on this peat or muck land and those employed on some of the mineral soils. Crops of rape and mustard for seed, of wheat, barley, roots and potatoes were seen everywhere.

This so-called "marling" has been tried on the peat overlying the sand but when the sand alone was applied the results have been discouraging. With improvements in the drainage it is quite possible that this type of peat also will be worked, but no doubt a different system will have to be used in reclaiming it. It is recognized by some as being good grass land if properly fertilized, but with the flood situation as it is the owners hesitate to invest much money in fertilizers.

Norfolk is noted for its pastures and for the number of cattle an acre will support. Some rich pastures on alluvial soil will fatten two steers per acre per year. On the peat land one sees very few animals other than the horses used in the farming operations, the land being farmed with the crops mentioned above. Practically all the straw produced is ordinarily baled for the city markets, but because of the increased

acreage of wheat grown during the war the Fens farmers in some sections now have a surplus of straw.

Land values are similar to those in the better farming districts in this country. Peat land of the best type is held at from 40 to 50 pounds per acre—some as high as 75 pounds, equivalent under ordinary rates of exchange to $200 to $350 per acre and in some especially favored sections the prices are even higher than this.

PEAT AS BARN LITTER.*

By Otto I. Bergh.

North Central Experiment Station, Grand Rapids, Minn.

Dairying and the growing of potatoes are the main lines of farming in the cut-over-timber regions of Minnesota. Most farms are yet relatively undeveloped. The area under cultivation is very limited. The production of winter roughage for the cattle has been, and still is, the limiting factor and the most immediate problem for the farmer to overcome. It is necessary for him to conserve to the utmost all the roughage from the crops he raises. One way of doing this is to use peat in place of straw for stable litter and save the straw for feeding purposes.

The North Central Experiment Station has, therefore, carried on investigations in preparing peat for litter. The first method used was similar to that in vogue in northern Europe, digging the peat up with tile spades and piling it in ricks to dry, then it is placed under cover and ground into litter as it is needed in the barn. We have also put the dry peat slabs through the ensilage cutter and blown it into a storage bin in the barn. This operation resulted in very desirable litter having the consistency of wheat bran, fluffy and soft. However, this method entails too much labor, making the peat expensive.

The second method, and the method we recommend and are using at present at this station, is to prepare the peat on the open bog by plowing and discing. A drained bog is necessary for this purpose. A crop such as oats and peas is grown and harvested for hay some time during July, after which, the surface of the bog is disced into a loose, pulverized condition and during dry periods it is hauled into a storage shed built

*Read at the Annual Meeting, Minneapolis, Minn., Sept. 22, 1919.

First method of preparing Peat for barn litter purposes. Labor cost makes this method inadvisable.

Second method of preparing Peat for barn litter purposes. Peat dried on bog by discing, prepared with small cost and labor.

on the principle of a corn-crib,—good roof and open sides. A winter's supply of peat can thus be prepared at small expense.

The litter so prepared is used both as a bedding in the stalls and an absorbant in the gutters, resulting in:

1st. Clean barn and clean cows.

2nd. In the saving of the straw, formerly used for litter, for feeding purposes.

3rd. Increasing, approximately doubling, the fertilizer out-put from the barns. The peat adding humus and also a considerable amount of nitrogen to the stable manure.

4th. Conserving the urine for fertilizer purposes. On the average farm the urine is usually wasted. Conserving the urine is important as it contains approximately 70 per cent of the Nitrogen and 90 per cent of the Potash in the excreta from the animals. The urine being the more important fertilizer produced by the herd.

The value of stable manure as indicated by trials carried on at this station with ten tons applied once in a three year rotation of oats, clover and timothy meadow, and potatoes is equivalent to the following average annual crop increase per acre over a period of five years: 7.4 bushels of oats; 763 pounds of clover and timothy hay; and 93.5 bushels of potatoes. Which, according to present prices,—Oats, 75c per bushel; Hay, $20.00 per ton; Potatoes, $1.50 per bushel, will amount to $153.33. That is, one ton of manure is worth $15.33—the indirect profit from live stock conserved and increased by the use of peat as barn litter.

THE DEVELOPMENT OF MARSH SOILS IN WISCONSIN.*

By A. R. Whitson.

Dept. of Soils, Wisconsin College of Agriculture.

Since Wisconsin has between two and one-half to three million acres of marsh land, the problem of their development was early recognized as one of the greatest importance. This matter was brought to the attention of Professor F. H. King, recently come to the College of Agriculture as Professor of Agricultural Physics in 1890. Farmers reported that on marsh land, recently drained, corn failed to make satisfactory growth on portions of most fields. He conducted some experiments during the next few years to determine the influence of drainage and of the use of lime for improving these soils. These

*Read at the Annual Meeting, Minneapolis, Minn., Sept. 22, 1919.

studies were largely negative and in 1895 Professor King undertook a study of the fertilizer requirements of these soils, following somewhat the lines of experimental work conducted by Professor H. A. Huston, then director of the Indiana Experiment Station. That year he demonstrated the very marked benefit to these soils from the use of stable manure and of potash fertilizers in various forms, though neither phosphates nor lime were beneficial. This work was done at Madison, which is within the limestone section of the state where the marsh soils are almost entirely prevented from becoming acid by the lime brought from surrounding higher land by seepage water.

The writer then took up the study of marsh soil requirements in 1904, conducting experiments in Marinette County in the northeastern part of the state on very acid peat marsh in the sandstone section. These experiments demonstrated the fact that phosphorus was needed in soils of this type even more distinctly than was potash, though both are needed to secure anything like satisfactory results. The following table illustrates the results secured that year in the treatment of this soil for the growth of different grasses:

Hay Per Acre Grown on Virgin Peat Soil Under Treatment with Various Fertilizers.

Treatment	Timothy and alsike clover	Fall Meadow oats	Meadow fescue	Fowl Meadow grass
	Lbs.	Lbs.	Lbs.	Lbs.
Potash	160	224	576	512
Acid phosphate	960	1,024	1,600	1,984
Acid phosphate and potash	2,080	2,080	1,792	2,430
No treatment	0	192	416	448
16 Loads of manure per acre	2,816	2,400	2,080	2,272

During the following few years experiments were conducted at Marinette and begun at Phillips and Mather, the former on raw peat land underlaid by clay in the granitic area of the northern portion of the state, and the latter in the sand stone or moorland district of the central part of the state.

All of this work tended to demonstrate fully the absolute necessity for the use of mineral fertilizers on this class of soils. It became evident that we have three quite different types of peat land in the state,—first, that in the limestone section, practically all of which is non-acid because of the lime carbonate brought it by seepage waters, though occasionally

toward the central part of the larger marshes small tracts of slightly acid soils are found.

In this portion of the state potash is the only mineral element it is necessary to supply in the majority of cases, though in a small percentage of cases we have found that phosphorus was also needed, and we recognize the fact that the continued cropping of these lands will undoubtedly bring them to a point at which phosphorus will be needed quite generally.

The continual need of potash will apparently vary somewhat with the depth of muck or peat. In some cases where it is comparatively shallow; so that settling during a few years of cropping permits deep plowing to reach the clay or silt subsoil, and some stable manure is used, the special need of potash fertilizers quite largely disappears.

The muck and peat soils of both the sandstone and granitic areas of the central and northern portions of the state require phosphate and potash fertilizers, in all cases at least after one or two years of cropping following breaking.

The need of lime in Wisconsin soils has been studied only to a slight extent. That it is not needed in many cases on raw peat land has been abundantly shown. In other cases there seems to be a need for the application of this element as well as of phosphorus and potash. Probably the most marked instance of that has been met at Phillips in Price County on a raw peat underlaid by clay subsoil.

The relation of peat lands to frost has also been found to be of great importance. In the study of soil temperatures on the marsh land of the cranberry regions of the state conducted by the writer beginning in 1903, it was learned that the condition of the soil very greatly affects the formation of frost during cold nights. The temperature 2 inches above the surface of poorly drained peat land covered with grass and cranberry vines was found frequently to reach a minimum temperature during the night of from 8 to 12 degrees lower than occurred on well drained sanded marsh. Temperatures 1 foot above the soil was found to frequently reach the freezing point over the grassy marshes, while no freezing occurred over the sanded and well drained portions of the marsh. A full study of this matter, made by the writer, assisted by O. G. Malde, and extending through several years, has fully demonstrated the great influence of the physical condition of the soil on the formation of frost, at least within a short distance above the surface of the ground.

The mechanical condition of this soil, both with reference

to soil temperature and foothold offered to germinating and growing crops, has been found to be of great importance. The use of a heavy roller as practicable to firm such soils is of very considerable importance.

The commercial development of the marsh lands of Wisconsin has had an interesting history. Following the encouraging experience in the organization of drainage districts in Illinois and in Indiana, the Wisconsin legislature has taken an active interest in the development of marsh lands by enacting laws providing for the organization of drainage districts which were incorporated and received authority to issue bonds for drainage operations. In the development of these drainage districts, many mistakes have been made, partly due to failure to recognize the necessity for complete drainage systems rather than simply a few outlets, and also partly due to deliberate fraud on the part of land manipulators.

Some who had experience in the development of marsh land in Illinois and Indiana on soils similar to those in southern Wisconsin, that is, underlaid by limestone rock, undertook to develop large tracts in central Wisconsin in the sandstone section, and failed to recognize the differences in the character of the soils, and also failed to consider fully the fact that frost is liable to occur on this type of soil almost any month of the year, thus greatly lessening their adaptability to such crops as corn and potatoes to which they would otherwise be well suited.

Partly through ignorance and partly through wrong intentions, promoters of these enterprises pushed the development of these lands and brought in a large number of people, mostly from outside of the state, who were also ignorant as to the requirements for success in the development of marsh lands in these locations and were, therefore, doomed to failure and disappointment to a considerable extent.

This experience gave the development of marsh lands in central or northern Wisconsin and in other portions of the state where marsh lands occur in considerable sized tracts, a set-back for several years. Lately, the recognition of the necessity of more complete drainage, the proper fertilization of the lands, and the growth of crops adapted to these conditions, have brought about very much greater success, and we seem now to be started on the right road toward the profitable use of these lands.

It is now evident that with proper management most of the marsh land which is capable of drainage can be developed successfully for agricultural use. The drainage must be

thorough. This includes adequate deep outlets with the necessary lateral open ditches and tile drains. Lateral tile lines may be placed deep; that is, from 3 to 5 feet and when deep may be at considerable distances apart and yet give good drainage. The most satisfactory location for the tile is near the bottom of the peat where this depth is such as to give a satisfactory depth of tile; that is, where it is not less than 2½ feet nor more than five feet in depth. Tile from 6 to 10 rods apart and varying from 4 to 5 feet in depth will give good results.

The crops best adapted to the majority of these lands include hay, especially timothy and alsike clover, buckwheat, soybeans, and corn where the danger from frost is not too serious. Rye is the best cereal, though certain varieties of the others can be grown under favorable conditions. Certain special crops are also adapted to these lands when properly managed. These include cabbage, onions, celery, and sugar beets. The quality of the hemp fire is probably not so good when grown on this land as when grown on upland soils.

The use of the proper fertilizers is of the utmost importance. On the non-acid marshes, 100 to 150 pounds of high grade muriate of potash having nearly 50 per cent of potash is a good application for corn and 100 pounds for small grains or grass. On acid marshes, 300 pounds of a 14 or 16 per cent acid phosphate should be added for corn and 200 for the small grains or grass, or a mixed fertilizer having a composition of approximately 0-10-10 at the rate of 600 and 400 pounds respectively. Best results have been secured by broadcast applications of these amounts, disking it in preparing the ground for seeding or planting.

With thorough drainage, proper tillage, and the use of the right fertilizers, large yields can be secured. Yields of 90 bushels of corn, 250 of potatoes, four tons of timothy and clover hay have been grown. But the farmer who does not know the particular needs of this kind of soil will fail.

THE USE OF PEAT AS A FERTILIZER IN MICHIGAN.*

By Ezra Levin.

Michigan Agricultural College.

The importance of organic matter and nitrogen in our agriculture, the high costs, and cultural difficulties attending the replacement of these factors in the worn-out soils, have caused soil students to view with intense interest the possibility of peat as a source of organic matter and nitrogen.

In Michigan, an impetus was provided in the curtailment of stockyard manure which had been used in Southwestern Michigan; the high costs and insufficient supply forcing truck and orchard farmers to experiment with peat as a substitute.

In 1917, the writer believed that the record of experimental data warranted a sympathetic attitude to the use of peat as a fertilizer. After observation of numerous trials, carried out at the suggestion of the writer, by farmers in the state, the practice has been recommended advisable and profitable with the limitations as suggested in this paper. These observations have been made over a period of three years.

There have been objections to the suggestions made for the use of peat as a source of organic matter for application on the uplands of Michigan. These objections are stated so that the question may be freely discussed and perhaps such a discussion will stimulate further research on this important problem.

The objections which have been raised can be included in the following:

1. The nitrogen in the average peats is not sufficiently available to be profitable.

2. Admitting the value of peat as a fertilizer, it is against the principle of the conservation of natural resources to dig holes in soil which may at some future day be very valuable farm land.

3. The results do not show sufficient returns for the labor expended.

4. That there are many different types of peat in Michigan, from sphagnum bog to powdery muck and that the less decomposed types of peat will not reveal the value that is claimed or acknowledged for the black powdery types of peat.

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*It has been noted in the discussion of Muck Farm Management in Michigan that the term "muck" is reserved in Michigan for peat soils which are used for farming purposes, while the term "peat" is used to apply to it when used for all other purposes. This is merely an arbitrary distinction and is used for convenience in this paper.

5. The work of Bottomley of England, with bacterized peat has not been confirmed and has been seriously questioned by the results of experiments which have been repeated by others.

6. There are other sources for nitrogen and organic matter which are at least as available as muck.

In approaching the subject it is essential to point out that the muck farmers of the state depend for their livelihood upon literally selling the nitrogen from their bogs in their crop or stock. As has been indicated in a previous paper, the process of nitrification is the basis for the proper understanding of muck land agriculture; fertilization, cultivation, climatic conditions have an effect upon the acceleration and the repression of nitrification which affect the success or failure to raise crops. It is agreed that the plants grown on muck use the nitrogen made available in the muck. S. D. Conner, Indiana, has shown that nitrates may be formed to such an extent as to become toxic to plants. European investigators, examining the microbial factors in the breaking down of peat have contributed to the details of this important phenomenon by which the nitrogen in peat becomes available. Notwithstanding these facts, the objection is made that analysis show very little soluble nitrogen in various peat samples.

This evident anomaly may be understood by pointing out that the chemical analysis of a peat sample indicates that, at the particular time the analysis is made the nitrogen is or is not soluble; it means nothing as to changes that may take place in the peat. The same error that has caused serious difficulties in the interpretation of the analyses of peat contemplated for agricultural utilization has resulted in the attempt to discredit peat as a fertilizer. Peat is not like quartz sand or clay. It must be kept in mind that peat is largely organic in nature, contains food which provides energy for bacteria and will undergo changes rapidly and has in no sense the stability of the mineral substances which make up the body of upland soils. The red, fibrous, infertile swamp, containing materials toxic to plant growth, can be changed into the black fertile field several years hence. Similarly, it has been noted that peat which applied alone depressed the yield of crops and which by chemical analysis indicated no value as a fertilizer, was converted into a valuable soil amendment and fertilizer by composting with manure. Thus, by adding bacteria to accelerate the decomposition and supplying the compounds of the manure to the peat which neutralize the toxic elements, the nitrogen which had previously been shown to be unavailable by analyses, is made available. Peat bogs are natural

silos. Peat is "pickled" organic matter. The organic residues of plants which have been submerged and have accumulated, have been subjected to anaerobiosis for a long period. Toxic substances have been produced. It has stopped changing; it is manifestly misleading to judge the value of the peat as a source for humus and nitrogen by anaylzing material in this condition.

It may be well to quote several contributions in support of the point of view taken. F. E. Weiss, University of Manchester, abstracts the published results of carefully conducted experiments by a Scottish land owner in the early part of the 19th century. The writer has not been able to obtain the original treatises, hence the complete abstract is given

"It is not usual to review a publication issued a hundred years ago, but the interest which has been taken in the Manchester scheme for manufacturing bacterized peat may serve as an excuse for drawing attention to a pamphlet published in 1815, and bearing the title, 'Directions for Preparing Manure from Peat." The anonymous author had already previously printed and distributed in the form of a tract his discovery that common peat was convertible into a putrescent manure, equally powerful as farm yard dung for the cultivation of ordinary crops, giving instructions for conducting and accomplishing the process requisite for that purpose. The author, a large landed proprietor in Scotland, having occasion to scoop out from a hollow a quantity of peat moss in order to provide a space for a small artificial lake, found himself in a difficulty when faced with the problem of disposing of the mass of peat thus obtained, and being of a shrewd and practical turn of mind he tried a variety of experiments with a view of converting it into a manure. The experiments were undertaken in a truly scientific spirit, with a considerable insight into the manure of peat, and with as good a knowledge as was available at the time of the process of putrefaction as observable in the decay of animal and vegetable matter. Recognizing in the deposits of peat the accumulation of vegetable matter in a state of partial decay, the author noted that in its natural state further putrefaction was inhibited, and he supposed that this was due to the evolution of tannin and gallic acid which had been detected in it. 'Peat,' as our author tells us, 'when taken out of a bog is certainly not manure. If dried, it becomes fuel, and so remains if kept dry. But if exposed to the vicissitudes of the atmosphere in our climate, it becomes, in the course of years, a sort of vegetable

*Note: Journal Board of Agriculture, London, August, 1916.

mould; and, if mixed with the soil and cultivated, raises good crops of potatoes and other vegetables.'

"How to accelerate this process was the object of his experiments extending over six or seven years. He first tried the effect of mixing the peat with substances that would neutralize its acidity; but peat mixed with lime for twelve months and used as a top-dressing did no good for several years. He next mixed the peat with various forms of decaying vegetable and animal matter, and found that the putrefaction of these substances was communicated to the peat, setting up fermentative activity indicated by the rise in temperature and resulting in the production of a rich compost, very effective in the raising of crops. In the earlier experiments he used such substances as the refuse of fisheries, shamble dung, etc., and in 1802 he had already announced a successful experiment by which he produced ten tons of rich compost from peat made up with shavings of timber and the carcass of a horse, partly with, and partly without the addition of some old lime rubbish. The method he advocates in the pamphlet of 1815 as the simplest and most useful to farmers, however, is the mixing of peat with about a third of its weight of ordinary farmyard manure. The peat should be allowed to dry for a few months before carting. Then, after spreading a layer of six inches of peat, about ten inches of dung may be placed above the peat, then another six inches of peat, followed by four or five of dung. After a third layer of peat and dung, the whole should be covered with peat, making a heap about four to four and a half feet in height. In mild weather, seven cartloads of tolerably fresh yard dung is sufficient for twenty-one cartloads of peat moss, but in cold weather a larger proportion of dung is required. It is useful to add about half a load of slacked lime, about a load of ashes, but neither of these is essential. When the compost is thus made up it gets into heat in summer in less than a fortnight. If it gets too hot, it should be turned over and in doing this a little more peat can be added to the heap. When the heat subsides, it will be found that a very perfect compost has been formed, all the lumps of peat having been broken up. Used weight for weight, it will be found quite as good as farmyard manure.

"Our author's experiments proved successful, and his directions were circulated by many large Scottish land owners, among their tennants. It would be interesting to know to what extent the practice was adopted, and to what extent it has been kept up in Scotland. The growing scarcity of dung which is likely to increase with further development of me-

chanical methods of traction, may resuscitate this discovery of a bygone age, at all events, in those districts in which peat can be had practically for the cost of cartage. Apart from this possibility, it is not without interest to find that experiments made so long ago as the commencement of the last century showed without doubt that peat, consisting as it does, of partially decayed vegetable debris, contains the basis of valuable plant food, and if the latter can be rendered available to plants may become a useful manure.

In all probability, in the method recommended by our author, the acidity of the peat becomes neutralized by the ammonia contained in the drug, while decay-producing bacteria may percolate into the peat in addition to those normally contained in it, but whose activity is inhibited by the presence of humic acid.

"In very much the same way, the peat in Chat-Moss has been in the course of years transformed into a rich black soil of great fertility. Drained of its acid waters and neutralized with lime, it has been further enriched, both in nutrient matter and in decay-producing bacteria, by the addition of sewage, and has thus been rendered capable of promoting vigorous growth of crops."

It is interesting to note that the peat was of a type which gave no results when applied directly; the moss referred to was probably sphagnum; the experiments extended over six or seven years. Especially interesting is the relation of lime and manure to making the peat into ferilizer; the relation of the temperature to the decomposition; the abstractor's comment on the possibilities of peat relieving the manure shortage.

Dr. R. S. Kedzie, addressing the Michigan Horticultural Society in 1883, made this statement.

"In most part of the state there are muck beds easy of access. If barnyard manure is composted with an equal volume of powdery muck by placing these materials in alternate layers, and then turning the compost by shoveling it all over once in the spring, a month before it goes to garden or field, you will have double the volume of manure, scarcely inferior to well-rotted barnyard manure. Such compositing is not a process of dilution or watering, but a substantial addition of manurial matter. Muck contains nearly the same quantity of combined nitrogen (two per cent) as well-rotted manure, but this nitrogen is mostly in the inert or inactive form. By composting with barnyard manure the active fermentation of the animalized matter induces fermentation of

the muck, and some of the inert nitrogen is made active; any ammonia set free in the fermenting manure will be absorbed by the muck, and loss by leaching of the soluble salts will be prevented by the same muck. Prof. Gulley tried this method of composting at the college, and stoutly affirmed that he got as active manure and twice the quantity by composting with muck."

No comment is necessary beyond the reminder that Dr. R. S. Kedzie was an agricultural chemist of international reputation.

C. S. Robinson, Michigan, in a bulletin, "Utilization of Muck Lands"*, gives some valuable data on the question. In 1914 he says "It may be conservatively figured that the use of muck in connection with manure increases the value of the latter from each horse and cow about $15.00 per six months. This refers only to the actual plant food content and not to the increased value of the extra organic matter of the muck nor its beneficial action in controlling the decay of the manure."

He carried out experiments comparing peat and manure in large cylinders in the ground. Applications of acid phosphate, gypsum and lime were made respectively. He states in a discussion of the results, "In every case the nitrogen found in the available forms is much greater with the mixture of peat and manure than with either of the constituents alone."

"By the use of such a mixture nitrification is apparently accelerated and the inert nitrogen compounds made available more quickly than when these materials are used separately. If we assume that cattle produce 25,000 pounds and horses, 15,000 pounds of manure per 1,000 pounds live weight per year, and that cattle are kept in the barns six months of the year, we have an approximate production of 101,250 pounds in a herd of five cows and two horses. The fertilizer ingredients of this under ordinary conditions would represent a value of $120. The value of the manure would be practically doubled by composting with one-third its weight of peat containing two per cent nitrogen." Estimation at present figures would be close to $220.

It has been stated that there are other sources of humus and nitrogen which are cheaper than muck. This objection will not be sustained upon analysis. It depends on the individual conditions. A discussion of the use of peat as a fer-

*Note: Utilization of Muck Lands, Bulletin 273, M. A. C.

tilizer assumes that the individual is accessible to a desirable muck bed and that he can excavate the peat at a cost comparatively cheaper than the price of growing crops for green manure of the cost of fertilizers. Moreover, it takes many years to build up the humus content of a soil. On the light orchard soils in Michigan the serious difficulties in maintaining humus content with continuous plowing down cover crops have been recognized. If the use of muck is a short cut to increasing the humus content on our intensively developed uplands, the possibilities of its use on many western Michigan orchards is apparent. Observations for two years measuring each situation from the point of view of practical profitable farm practice has convinced the writer that the possibilities of the peat of Michigan as a source for humus has been demonstrated by the farmers of Michigan, notwithstanding that it has not received the endorsement and attention of soil investigators.

In recommendations for testing the value of peat as a fertilizer the farmer was urged to use the different applications, peat alone, manure alone, a mixture of peat and manure. Data were collected on the results of the application on different types of soil; various types of peat; different methods of excavation; use as a litter, and as an absorbant, etc.

1. Peat which is highly decomposed is more likely to give satisfactory results than the peat which is less decomposed when applied alone. (The type of soil is concerned. For example, a stiff clay will react to peat applied alone strikingly, whether the more or less decomposed types are used.)

2. Peat applied alone on acid soil will indicate very little value. Peat applied alone on the same soil limed may reveal good results.

3. Composting equal quantities of peat,—sphagnum, cedar, tamarack, sedge, huckleberry, or black ash,—and manure of various types, have given excellent results.

4. The less decomposed the peat, the longer time it should be composted with an equal quantity of manure. There are three factors to be considered—time, amounts, and climatic conditions.

5. Not a single case of composting has come to our attention in which the compost was not equal as a fertilizer to the same quantity of manure. In most cases the mixture of peat and manure was better than manure alone.

6. In several instances the peat alone depressed the yield as compared to no application, while the same peat composted with manure gave as good results as the manure alone.

7. In a few instances where farmers compared straw with peat as a litter, the peat manure was at least equal to the straw manure.

8. As an absorbent and as a litter, it has indicated a greater value than straw.

Peat is better than straw for horses' feet. Peat is valuable for conserving the fertilizing elements of dead animals. It has been used by many farmers in privies, closets, as a valuable deoderant, and for conserving the fertilizing value of human excreta.

A simple manner in which the sedge type of peat can be made available for use is to plow a number of furrows at a dry time of the year and set the furrow on edge. The sod will dry out rapidly and can be handled at a small expense.

The common dipper dredge is being used with success. Where the peat is of the loose type, well drained and finely divided, it can be dug by hand and hauled all winter. Numerous farmers in Michigan are doing it now.

A frequent question is, "How far can I afford to draw peat for fertilizer?" A conservative answer is, "As far as you can afford to draw wheat straw for its fertilizer value."

It has been stated that an objection has been raised on the grounds that it is a violation of the principle of conservation of natural resources to dig holes in what is to be valuable agricultural land. The same objection might be raised on the use of marl, or the use of coal, or the use of clay for brick. From that point of view all investigation which has to do with the use of peat for fuel should cease immediately. The assumption that mining nitrogen and organic matter which the uplands of Michigan need so seriously is destroying our natural resources, is untenable.

A recent California publication* dismisses the question of peat inoculation, with a letter pointing to the unconfirmed work of Bottomley of England. It states in the summary, "We regard the inoculation of peat as a useless procedure and an unnecessary expense to the farmer." Nothing is mentioned in the paper about composting peat and manure. The composting of peat and manure is in every sense of the term an inoculation of the peat. Certainly the author does not wish to imply that he regards the composting of peat and manure a "useless procedure." There is too much sound evidence to the contrary.

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*Note: Peat as a Manure Substitute, John S. Burd, California Experiment Station Circular 203.

Extravagant claims of some of the men selling peat for fertilizer are unwarranted, particularly, statements that deposits from which they excavate are superior to the peat on the neighboring farms. Every farmer who has peat on his farm can make a high grade mixed fertilizer at a low cost, comparatively, if he will compost peat with manure and add phosphoric acid and potash. This is not considering the value of the organic matter on the micro organisms. The writer takes the point of view that peat has a fertilizer value, and contains nitrogen and organic matter which can be used profitably on the highlands, and that it is an important agricultural fact which should be propagandized and extended. However, if men are desirous of exploiting the farmer by making extravagant and false claims as to the value of peat, they should be exposed and prosecuted.

CHEMICAL REQUIREMENTS OF PEAT SOILS IN THE LIGHT OF EUROPEAN EXPERIENCE.

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Introduction.

In dealing with the question of the chemical requirements of any particular tract of peat soil, one must differentiate between its **initial chemical requirements**—those applications which are necessary when the land is first brought under cultivation—and the **later chemical requirements**—those which, while unnecessary in the first year or even possibly for several years, before long become indispensable. To get a fair perspective of these and of the various other problems met with in peat land reclamation, as well as of the different means that have been evolved to meet them, one should consider the experience of European countries, where the agricultural use of peat lands has gradually developed during the last three centuries, in the course of which the various simpler methods of improvement have been subjected to a thorough trial.

In America field experiments on soils of this class have been on a very limited scale, and chiefly of a co-operative nature, while in Germany the Bremen peat experimental station was established in 1877, and the Swedish station at Jönköping has been in active operation since 1886. In addition to these

two, which for more than thirty years have been devoted exclusively to the study of the use of peat lands, there are others more recently established and usually working on a smaller scale.

Not until the sixteenth century do we find any record of the use of peat lands for cultivated crops, although it is probable some of the grass and sedge covered bogs had much earlier been used as pastures and meadows. The first use of peat soils for crop production came incidental to the preparation of peat for fuel, giving rise to the Fen Method, which was adapted to only those bogs that were near a market for the fuel and also were provided with water transportation. Soon after this arose the practice of burning the surface, and this method continued the almost universal means of farming peat lands until some sixty years ago, when Rimpau of Germany developed a Sand-Cover Method, involving the use of potash and phosphate fertilizers. This met with great success upon a certain type of bog and gave a great stimulus to peat land reclamation, but in the course of the next twenty years it was found unsuited to many extensive peat areas and now has given way almost entirely to the so-called Modern Method, in which use is made of commercial fertilizers, with or without lime, according to the character of the peat.

All the methods have in common, as a first step, the installation of a satisfactory drainage system, and as a second, an increased supply of plant food, especially of potash and phosphate.

Fen* Method of Holland.

During the sixteenth century this system was developed in Holland, incidental to the peat fuel industry, and down to very recent times has continued in use there, especially in the province of Croningen. In East Friesland also, in the adjacent portion of Germany, it was extensively employed.

All the low-lime bogs of Holland and North Germany show two distinct layers, the lower consisting of well decomposed, dark colored, heavy peat, and the upper of slightly decomposed, light brown, and but slightly compacted material. Only the former is prepared for fuel, and where there is no demand for the upper layer for some other purpose, such as for stable-litter, the disposition of it is a serious matter, greatly increasing the cost of fuel production. After the valuable lower layer had been removed from a portion of a bog

*From the Dutch word **Veen**, meaning "bog."

the resulting excavation, which served for the most economical disposal of this waste material, was filled with the shrubs, moss, and poorly decomposed peat of the upper layer as removed from the adjacent tract being prepared for excavation. A coating of four or five inches of sand, taken from the bottom of the adjacent canal, was added to the surface of this loose material and well worked into the peat so as to form a layer of the mixture about ten inches thick. To this was then applied a heavy dressing of compost made from street sweepings, stable manure, and other town refuse brought out from the cities as the return cargoes of the fuel boats. The function of the sand was not to furnish plant food, but to compact the loose mass of vegetable material and so improve the moisture supply, the compost providing the plant food. Crop production was maintained by the regular use of the town refuse. Such a method of reclamation was dependent upon several conditions which exist in the case of only a very small proportion of the bogs, viz., a suitable sandy substratum, water transportation to the bog, proximity to a city, and the use of peat as fuel in that city.

Later it was found, in cases where the peat was not to be dug out for fuel, that if the drainage were properly controlled, the coating of sand could be omitted, the surface needing simply to be cleared of moss and shrubs and then liberally supplied with compost or manure. But even with this modification, the use of the method was feasable only near cities which might serve as the source of manure. This might be designated the Modified Fen System.

In Ireland it appears that several hundred acres of bog were reclaimed by the Modified Fen Method about the middle of the seventeenth century (12, p. 394).

Burning Method.

This was developed during the seventeenth century on the low-lime bogs in the more remote portions of Holland and in northwest Germany and was in almost universal use in these countries down to the middle of the last century. The same method has appeared independently in various other parts of Europe and even in the United States, usually as the result of an accidental burning.

When the method was intentionally employed the bog was first drained by open ditches, then the surface was loosened by hand labor and the dry, loose material burned off each year for four or five years. Usually the first two or three crops proved quite satisfactory, but the yields rapidly decreased

until after five or six years they became so light that it did not pay to harvest the crop. These areas were then abandoned for thirty or thirty-five years in order to allow of the formation of a new layer of moss, shrubs, and loose peat. In the meantime five or six similar areas had been burned and exhausted. So if a family were to have forty acres of grain every year it was necessary to drain and care for two hundred or three hundred. In wet seasons burning was found impossible, and then there was no crop. The average returns were low and the isolated peat land farmers were usually in a state of poverty. This primitive method, continued largely until late in the last century, has now been almost abandoned in Europe.* In many places it has even been prohibited, largely because of the nuisance to the adjacent cities and towns of the great quantities of smoke which result from the burning.

The Burning, like the Fen Method, was employed almost exclusively on the low-lime bogs, upon which it was necessary to burn every year, the beneficial effect of a burning appearing to be exhausted by a single crop. However, it was practiced to some extent on the high-lime bogs, and these gave excellent returns in the first season and the beneficial effect remained marked, though in a gradually lessening degree, for several years.

Early Progress in Scotland.

At the beginning of the nineteenth century Scotland appears to have been far in advance of the countries of continental Europe in reclamation of their low-lime bogs, although neither that country nor England appears to have made any important contribution to the modern development of peat land reclamation methods.

In Ayrshire liming peat was tried as early as 1760 and good crops were grown soon after (7, p. 275). Anderson in his Treatise on Peat Moss, published in 1794, recognized the great importance of three of the most important modern practices, viz., liming, avoidance of over-drainage, and rolling, while at the same time he strongly condemned the prevalent practice of burning (2). Aiton (1) in 1811, in what may be considered the first treatise on peat land farming, endorsed Anderson's views on the above points, described suitable rotations and dealt with the desirability of the various crops for reclaimed bog-land. At the request of the Highland or

*It was revived in Germany during the recent war, due to scarcity of fertilizer and dearth of food.

Agricultural Society of Scotland, in a journey of over 2,000 miles, he had visited the chief districts of England and Scotland where peat was being successfully reclaimed. The methods employed he found to consist of liming together with either a covering of clay or the use of manure or of both; burning was used rather freely in preparing the land for the first crop. In many cases, he states, good crops were secured by liming alone (7, p. 227).

On the subject of liming Anderson wrote (2, p. 102): "Of all the manures that have ever been tried upon moss, no one can be compared to calcareous matter, under whatever denomination it may be applied, whether lime, marl, chalk or shell sand. If the quantity of calcareous matter be sufficient, the effects appear to be little short of enchantment."

Back of the great interest in the reclamation of peat land at that time lay the wars with Napoleon, Aiton writing (7, p. 345): "If we remain as at present, shut out from all the ports of Europe and America, nothing but the utmost exertions in every department of agriculture can preserve our independence . . . . beyond a single year of scarcely equal to 1782 or 1799. We cannot tell how soon such a year or worse may come."

The shallow high-lime peat of the Fens country in England, where underlaid by clay, has long been reclaimed through burning and then coating with clay (6, p. 259; 10), but as late as 1913 it was considered doubtful in England whether the reclamation of the low-lime peats would be profitable except where their situation was unusually favorable (11, p. 119-123), as in the case of Chat Moss, a large bog lying at the edge of Manchester on the Liverpool road. It is of interest that this bog, which has eventually been reclaimed by town refuse from the former city, probably with liming, was in process of reclamation on an extensive scale when visited by Aiton in 1807.

Sand-Cover or Rimpau Method.

Thus the situation was as late as 1862, a choice between the Fen Method and Burning, when Rimpau completed the development of his Sand-Cover Method of reclamation, which proved a glowing success upon his own large tract of peat land. He had developed his system upon his own land, entirely at his own expense, and through his farming operations became well-to-do. Many of his neighbors adopted his system and succeeded. The expression "peat land reclamation" became synonomous with the Sand-Cover or Rimpau Method. While his method is now of only very limited appli-

cation, on account of the rapid advance in the art and science of peat land farming, his work is very important, as it marked the real beginning of the application of agricultural science to these soils, and indirectly led to the establishment of the first Peat Experimental Station.

A brief sketch of the work of Rimpau appears necessary in order to explain not only the Sand-Cover Method, but also the disappointments of the Prussian government in the first large peat land reclamation project of recent times. Rimpau born in 1822, was a city boy, but early developed a preference for agriculture. In Brunswick he attended a school, where his teacher was the agricultural chemist Sprengel, who was devoting much energy to the study of peat land reclamation. Later Rimpau acquired a practical acquaintance with agriculture, became manager of a farm and made trips to England, Scotland, Belgium, and Holland, to study agricultural methods, and then finally spent two years at the pioneer school of agriculture recently established at Hohenheim in Würtemberg. In 1847 he purchased the large estate of Cunrau, containing about 4,000 acres, of which about 1,200 were covered with peat well supplied with lime, well decomposed, only from 1 to 4 feet in depth and underlaid by coarse sand. This estate, valued at $135,000, carried a mortgage of about $128,000 at the time of purchase and Rimpau's financial condition soon became serious. To extricate himself from the embarrassment he strove to make the most of his peat land. The burning method, which had been used on the estate before he purchased it, was employed, but it gave disappointing returns and was gradually abandoned. On a part of the bog on which the peat layer was only from 6 to 18 inches thick he tried mixing the underlying sand with the peat by deep plowing, but the results, while encouraging, were still far from satisfactory.

Next Rimpau made use of practices which he had seen in the Fen Method in Holland, and along with the manure tried acid phosphate which had been recently introduced. Later, as the German potash mines began to place potash salts upon the market, he tried these and found them so beneficial that he discontinued the use of manure entirely on his peat soil, employing potash salts together with a phosphate fertilizer. So his system as finally developed, consisted in covering the levelled surface of the bog with a layer of sand 4 to 6 inches in thickness and then fertilizing with only commercial fertilizers, potash and phosphate, the peat beneath the sand layer furnishing the necessary nitrogen and lime as well as water. While in the Fen Method the sand and peat were thor-

oughly mixed, in Rimpau's Method all mixing was avoided, the subsequent cultivation being purposely so shallow that none of the peat was brought to the surface.

Founding of the First Peat Experiment Station.

In 1886 when Prussia came into possession of Hanover with its enormous areas of peat lands belonging to the crown, the government at once formed plans for the reclamation of these waste lands. The Fen Method, common in Holland, was impractical, while the Burning Method had not given satisfactory results and further had come into great disfavor with adjacent cities and towns, but the new Rimpau Sand-Cover system seemed to be succeeding wherever it was tried and had no objectionable features.

Four years later came the Franco-Prussian war and great numbers of French prisoners of war were sent to the great Hanoverian bogs and set to digging ditches ad preparing the lands for cultivation. When the war was over and the prisoners had gone home the farming of the drained land was undertaken, but the results were most disappointing. This seems to have been the first distinct realization that not all peats are alike from a reclamation standpoint, that Rimpau had devised a system of reclamation for one kind, while the Prussian government had been working with a very different kind. The Germans appear to have overlooked the experience of the Scottish peat land farmers with lime who seventy years before had recognized its importance the matter being dealt with by Anderson (2, p. 227) in 1794 and Aiton in 1811 (1).

To meet this situation the Prussian government in 1876 appointed a Peat Land Commission as a permanent advisory board to its Ministry of Agriculture. The first measure the newly created commission suggested was the establishment of an experimental station to study the scientific foundations of peat land reclamation. The next year such a station was founded near Bremen, in the midst of the large Hanoverian low-lime bogs, and within a few years it had made such progress in the solution of the peat land problem that it could advise upon which peats the Sand-Cover Method might safely be applied, and had developed methods suited to those upon which Rimpau's Method would prove a failure. The former were those that were shallow, well-decomposed, and well supplied with lime. From the field and laboratory examination of a bog the methods of reclamation could be very satisfac-

torily decided before it was necessary for the owner to expend anything for drainage or clearing.

Other Peat Experimental Stations.

After the success of the Bremen station became evident, experimental stations, farms and fields were established in various other countries on the continent of Europe, viz., in Sweden, Austria, Bohemia, Norway, Denmark, Finland and Russia (in what is now Esthonia), while in Germany, where it soon was found that the conclusions arrived at as the result of the experiments at Bremen could not always be safely applied to the peat lands of districts in which the climate or the soil was quite different, several other experimental stations were added and numerous experimental farms and fields.

Development of the Modern Method in Germany.

In the German Empire, according to the most careful estimates, there are about 5,000,000 acres of peat land, about equally divided between high-lime and low-lime bogs. Of this area nearly four-fifths lies in Prussia. Before the war approximately 500,000 acres of this had been reclaimed and was producing grains and inter-tilled crops or had been converted into highly productive meadows and pastures. This improved land, like the wild, is about equally divided between the high-lime and low-lime bogs. Table I, from Fleischer, shows the chemical composition of typical German peat soils.

No more reliable summary of the chemical treatments required by the German peat soils is to be had than that given in 1913 by Fleischer (5), who was the first director of the Bremen peat experiment station, founded on February 4, 1877, and who during the following thirty-six years had been officially connected with it. He thus had had a long experience in peat land reclamation, being throughout this whole period most intimately associated with the development of the Modern Method of peat land reclamation and management, even being commonly referred to as the founder of the Modern Method.

Fleischer considers regular potash fertilizer necessary for all peat soils with the exception of a few bogs upon which the application may be somewhat lessened, or even entirely dispensed with, such bogs having been enriched by frequent floodings with a potash-carrying mud. The need of phosphate applications he considers not so nearly universal, as while these are necessary on all low-lime bogs and on most of these high in lime, there are occasional bogs of the latter kind which

TABLE I. Composition of Typical German Peat Soils.
(From Fleischer.)

		Ash P. ct.	Phosphoric acid P. ct.	Potash P. ct.	Lime P. ct.	Nitrogen P. ct.
High-moor	(Low-lime bog)	3.0	.10	.05	0.35	1.20
Low-moor	(High-lime bog)	10.0	.25	.10	4.00	2.50
Transition-moor	(Intermediate bog)	5.0	.20	.10	1.00	2.00

are so richly supplied with phosphate that the use of a phosphate fertilizer is unnecessary.

While recognizing the need of lime on all lime-deficient bogs and advising for these an initial application of from 1 to 2 tons of burned lime, or its equivalent of ground limestone, he emphasizes that very heavy applications of lime, even on very lime deficient peats, have proved not only unnecessary but actually injurious.

Fleischer warns against omitting the annual application of fertilizer. The quantities of the different fertilizers he recommends agree with those given in Table II. The application of phosphate indicated is for those bogs on which the peat carries not more than 0.50 per cent or phosphoric acid. On peats richer in phosphate than this he advises that the question of its use be decided by laboratory investigation or field trials. As a simple method of estimating the amounts of the fertilizers required by a hay-field after the first three years, he assumes that every ton of well-cured hay taken from the field removes 40 pounds of actual potash and 13 pounds of phosphoric acid. Thus three tons of hay per acre would remove the equivalent of 300 pounds of 40 per cent potash salts and 250 pounds of high grade (16 per cent) acid phosphate. For pastures much smaller applications than these may be made, because so much of both the phosphate and the potash is returned to the soil in the excrement. At the Bremen station 50 pounds of potash and 30 pounds of phosphoric acid per acre each year have been found to suffice for the maintenance of the productivity of pastures.

Ven Seelhorst, who is at present Director of the Göttingen Agricultural Institute and Experimental Farm, and who, for about thirty years has devoted much attention to the subject of peat soils, being the author of the first modern textbook (14) upon the subject, agrees fully with Fleischer as to the fertilizer requirements. He further states in regard to low-lime bogs that have been burned over and cropped until they

no longer give profitable crops, that these respond to fertilization like unburned bogs.

Bersch, who for many years has been in charge of much of the peat soil investigation in Austria, and who is the author of the best textbook (3) on the subject, states in the last edition of this book (1912) that on all low-lime bogs both phosphate and potash, in addition to lime, must be used, while potash is necessary on all high-lime peats, and phosphate also on most of them. While nitrogen fertilizers are rarely of use on the latter, they are usually necessary on the low-lime peats, except with legume crops. As a guide to the approximate amounts of fertilizers and lime needed, he suggests the amounts shown in Table II. The actual amounts advisable will vary somewhat according to local conditions, less potash being needed on the bogs of south Germany and the Alpine lands than in north Germany, where the oldest experimental fields are located, the natural supply of potash in the latter being the smaller. With legume crops, or grass fields containing clover, the nitrogen fertilizer is to be omitted on low-lime as well as high-lime bogs.

TABLE II. Rates of Application of Fertilizers for Peat Soils According to German and Austrian Experience (After Bersch), 3, p. 165).
Rates are given as pounds per acre.

	High-lime bog	Low-lime bog
First Year of Cultivation (Potatoes).		
Lime (CaO)	None	1800 to 3500
Phosphoric acid (P_2O_5)	110 to 180	180 to 270
Potash (K_2O)	110 to 120	180 to 270
Nitrogen	None	45 to 70
Second Year (Potatoes on Low-lime and Meadow on High-lime Bog).		
Lime	None	None
Phosphoric acid	55 to 70	110 to 160
Potash	110 to 125	110 to 125
Nitrogen	None	30 to 55
Third Year (Winter Rye on Low-lime and Meadow on High-lime).		
Lime	None	None
Phosphoric acid	25 to 55	110 to 125
Potash	55 to 70	90 to 110
Nitrogen	None	40 to 55
Fourth Year (Oats or Meadow on Low-lime and Meadow on High-lime).		
Lime	None	700
Phosphoric acid	Replacement*	Replacement
Potash	Replacement*	Replacement
Nitrogen	None	40 to 55

*The quantity needed to replace that removed in the crop of the previous year.

Von Seelhorst (15), writing early in 1914, mentions the enormous advance in the price of peat lands in Germany, especially of the low-lime bogs, for which in the last 20 years the price had not infrequently risen fifty-fold. In the unreclaimed state the German low-lime bogs, as he states, provide only a scanty pasturage for cattle and sheep or are entirely unproductive, while the unreclaimed high-lime bogs are largely used as meadows and pastures, which according to Fleischer, may be expected to give an annual return of from 50 cents to $1.00 per acre. In a careful computation he estimates that the 5,000,000 acres of German peat land would support a population of 2,500,000 if it were all reclaimed and equally divided among (1) meadows, (2) pastures, (3) grain crops, (4) potatoes and forage crops.

Rapid Progress in Sweden.

In Sweden, which has about 12,000,000 acres of peat land, a Peat Land Cultivation Society was organized in 1886 which at once established a peat experimental station at Jönköping and a few years later experimental farms at Flahult and Torestorp. The society has a membership of about 3,000. Up to the end of 1909 about 6,000 bogs had been examined and more than 4,000 samples of peat soil had been analyzed. Since 1904 more than 150,000 acres of peat land has been reclaimed with the assistance of the Jönköping station.

The first director of the Jönköping station was Carl von Feilitzen, who upon his death in 1901 was succeeded by his son, Hjalmor, the present director. The latter, thus associated with the work for over thirty years, states that it has been found that practically all the Swedish peat soils are so deficient in both potash and phosphate that in order to obtain satisfactory yields both constituents should be supplied in fertilizers, not only in the first year of cultivation, but in each subsequent year. Often at first potash has been found to show less effect than phosphate, but even where in the first season it has caused little or no crop increase, it has in the end proved more profitable to supply it at once rather than to wait until the crop yields have become unsatisfactory from want of it. Many of the Swedish peat soils are deficient in lime, and these need a liberal dressing in connection with the first cultivation, two or three tons of ground limestone per acre, while afterwards small quantities should be applied at intervals of several years, such as one ton once in a rotation, or, with permanent meadows, one ton once every four or five years. For crops other than legumes such Swedish peats need also a nitrogen fertilizer.

The Swedish station has found that commercial fertilizers alone do not suffice to maintain maximum yields, and for this reason recommends, in addition to the necessary amount of commercial fertilizers, an occasional light application of stable manure, in order to provide bacteria of decay.

As the initial phosphate application Von Feilitzen recommends an amount of fertilizer equivalent to from 425 to 850 pounds of acid phosphate per acre (68 to 136 pounds of phosphoric acid), decreasing this from year to year until there is supplied each season the equivalent of the amount removed in an average crop, which will vary from 100 to 250 pounds of 16 per cent acid-phosphate. As the phosphate does not leach out, a liberal reserve is thus left in the soil at all times.

Potash, on the other hand, leaches out to a great extent, and if supplied in larger amount than the crops need it may be largely lost. Therefore the potash salts are applied according to the amount removed in the crop, viz., from 150 to 450 pounds of 40 per cent potash salts per acre.

In order to secure the full effect of the phosphate at once it has been found that it should be well worked into the soil, as by discing, it not being put down deep enough by a light harrowing.

Von Feilitzen, like Fleischer of Germany, warns against neglecting the annual fertilization, stating that the omission of fertilizers in any one year, which unfortuately may happen, almost always revenges itself by the resulting decrease in yield (13, p. 44).

Backward Situation in Ireland.

No other country except Finland has such a large proportion of its surface occupied by bogs as has Ireland, where there are more than 3,000,000 acres, constituting about one-seventh of its land surface, with the peat layer varying from 2 to 40 feet in thickness and with an average depth of 25 feet. At present it is of little agricultural value, altho "there are extensive areas capable of being easily drained and in some cases that require no drainage whatever to bring them into profitable cultivation," (7, p. 724). The reclamation of these is dependent entirely upon proper fertilization.

Systematic field experiments were begun first in 1914 and have been reported for three widely separated bogs, one near Naas, in County Kildare, another near Furbane in Kings County, and the third near Lough Neagh in Tyrone County. Rape, rye and potatoes were tried on each, using the treatments indicated in Table III. The results on all three bogs

TABLE III. Influence of Various Treatments upon Crops on Three Irish Bogs in 1914 and 1915, (7 and 8).

	Rape	Rye			Potatoes		
	Relative growth (Alsike on all 3 bogs)	Grain and Straw Pounds per acre			Pounds per acre		
Treatment		Kildare	Kings	Tyrone	Kildare	Kings	Tyrone
None	No growth	0	7	7	2,000	850	775
N, P, K.	No growth	64	39	32	3,700	4,875	575
N, K, L.	Little growth	314	525	425	3,400	2,725	2,575
P, K, L.	Fair growth	1,525	2,375	1,925	5,503	8,575	5,425
N. P. L.	Fair growth	1,639	1,900	1,450	6,000	5,725	6,300
N, P, K, L.	Good growth	2,739	3,375	2,825	10,000	13,000	9,300

N=75 pounds nitrate of soda and 75 pounds sulphate of ammonia per acre.

P=600 pounds acid phosphate per acre.

K=300 pounds kainit per acre.

L=2 tons burnt lime per acre.

were very similar and indicate that lime is the limiting factor, with phosphate second in importance, while potash and nitrogen fertilizers are necessary in order to secure maximum yields. In the case of rape, no plants survived where lime was not applied, even when nitrogen, phosphate and potash fertilizers were used, and the rye did little better, but the potatoes showed less need of lime than of phosphate.

The relatively greater importance of phosphate than of potash in the first season is similar to that found for some peat soils in Sweden.

The Irish bogs, as represented by the three mentioned, are of the kind most expensive to reclaim.

Classification According to Chemical Requirements.

The results secured in Holland, Finland and Norway are so similar to those reported for Germany and Sweden that they do not need special mention.

Thus European experiments indicate two main groups of peat soils—**low-lime** and **high-lime**, with four subdivisions of the latter, or five classes in all.

I. **Low-lime Peats.**

These need lime, potash and phosphate, and also, except for inoculated legumes, a nitrogen fertilizer.

II. **High-lime Peats.**

1. Peats which at first are productive without fertilization. These are infrequent.

2. Peats needing only potash. These appear to be very rare and to be confined to soils with an especially high content of phosphate. The need for potash may be expected to continue indefinitely, while later phosphate also may become necessary.

3. Peats needing only phosphate at first. Very rare in Germany, a little more frequent in Sweden, but perhaps not uncommon in some parts of Russia, according to Kossowitsch (9, p. 166).

4. Peats needing both potash and phosphate when first brought under cultivation as well as in later years. These are by far the most common on the high-lime bogs.

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PEAT CLASSIFICATION.

Dear Editor:—

In the Journal of April, 1920, I note with interest you have requested correspondence on above subject, with the object of arriving at a basis from which to work to determine the suitability of peat deposits for a given purpose.

While some method of determining the different peat growths may be worked out eventually, I am afraid if we try to tabulate the different deposits according to their growths we shall have great difficulty in deciding on that infinitely fine line which will spell yes or no in relation to a given deposit for a specific purpose.

To my mind, we cannot determine the suitability of any given deposit by the growths composing the deposit, because these growths will have changed as the deposit has aged, or as the water level has changed, or as wind blown seed may have started another growth on the swamp surface, so that if we decide that Sphagnum is, for instance, the best fuel peat, we may find that moss for 2 feet on the surface, then find no more till we get ten feet down. On the other hand, the swamp may continue ten to twenty feet Sphagnum and the surface be covered with fern, or grass growth.

Your article is of great interest to me at the moment, because for the last three months I have been trying to locate a suitable peat deposit in the vicinity of Minneapolis, Minnesota, from which deposit will be taken 1,000 tons of air-dried machine peat fuel per day, assuming we would have 150 working days per year.

You are probably aware that Minnesota contains as much peat as all the rest of the United States put together, and yet, in the locality above referred to, I have had difficulty in selecting a deposit I would consider not perfect, but good enough to operate on.

As I am more familiar with peat from an industrial standpoint, rather than from an agricultural standpoint, I will note briefly some observations along the selection of a deposit for fuel purposes.

Let us assume we require 100 tons of machine peat fuel per day. The first point to settle is, where is the nearest deposit to a railroad, or market.

Second, having found a deposit within three miles (not over) of rail, or market, what is the nature of such deposit?

Third, will the peat form a dense, heavy block, which will

stand transportation without too much loss from abrasion, and will the volume per ton permit of its being transported any great distance at a price which will not kill the profits?

Fourth, what is the ash content and the B. T. U. value? I have raised the question of ash last, because even if this were only 2% and the peat, owing to its composition, could not be formed into hard, dense blocks, by maceration, the deposit would be useless for the purpose intended. This question of ash is somewhat important in some cases,—in others, it may be overlooked within limits, and if other fuels are selling at a high price in the locality under consideration, it may be a paying proposition to use peat having an ash content as high as 20%, provided cost of manufacture and transportation will admit of selling the peat fuel at a price low enough to compete with other fuels.

About thirteen years ago, I was requested by the directors of a peat fuel company in Michigan to determine why they could not make good peat fuel after spending $125,000.00 on buildings and machinery. They owned 650 acres of the best muck land in the country, peat from one to three feet deep, ash content from 50 to 75%, and they wondered why, after spending $125,000.00 on equipment, they could not make peat fuel, "well!"

Another time I was asked to buy a peat fuel outfit which had been imported to this country at a cost of $30,000.00 and tried out on a marsh composed of leaves and sand. It would not hold together after maceration and contained 35% mineral ash, "well?"

In another instance, my opinion was asked regarding a Sphagnum deposit in Canada. I said the deposit, being too new and, furthermore, full of roots of firs, spruce, etc., was unsuited for fuel manufacture. The promoters, however, went ahead for two seasons. They quit after the money was gone. This was not ash to blame, but lack of experience, "well?"

Were it not for the fact that my further reference to failures might weary the reader, I could go on and give instances of scores of cases where peat projects have failed thru lack of knowledge of the very points you raised—the classification of peat.

As the growths change during the make-up of the deposit, so do they change on the same swamp within very wide ranges, so that it becomes necessary to change the mechanical treatment of the peat as often as the plant growths themselves change.

For instance, on a swamp of about 500 acres, I decided

to use a certain section for peat fuel purposes, but owing to drainage conditions, it was necessary to operate the fuel machine along a length of about three-quarters of a mile to facilitate drainage. In this three-quarters of a mile the growth of the peat changed from pure Sphagnum with fern covering to Sphagnum and eriophorum with a species of wire grass on top.

The fuel from one section of this bog was all that could be desired—from the other, the fuel was brittle and would fall to pieces when dry, but I wanted to use both kinds for fuel purposes and wanted to make good fuel in both cases, and so, not being able to change the peat make-up, I changed the maceration process, with the result that a good fuel was obtained in each case.

I have wandered somewhat from the point in question and have looked upon the matter in its larger aspect, because I have often found that peat which appears to warrant exploitation was useless for fuel, not altogether on account of its high ash content, but on account of its lightness, friability, or lack of pectose.

It would appear to me that even if we arrived at some sort of tabulation of deposit growths and their availability for specific uses, we should then have to approach such deposits from the standpoint of suitability for mechanical treatment. In other words, let us assume a built-up deposit of sphagnum, eriophorum and carex on a sandy subsoil, ash content from composite sample, say 8%, we would assume that such a growth would produce good fuel, from a swamp say 10 feet deep. So it should, and would in most cases, but suppose the investigator overlooked the fact that the water level had varied within wide limits and aeration of the peat growths had taken place from the time the bog started to grow, well, then we would have another condition set up, which has nothing to do with the growth, or ash, but will spell success or failure from a peat fuel standpoint, unless those in charge of operations are familiar with the treatment required to produce a non-friable fuel from raw peat of this nature.

It is perhaps unfair to tackle this matter in the manner I have done, without trying in some way to help solve the question to some small extent.

Well, let us assume the location is large enough and near enough to market, or rail, to warrant further investigation—then we look at the lay of the land, the probable depth of deposit as indicated by the surrounding ground, then consider the cost per acre of clearing (and right here is another point,

if the deposit contains roots of firs, spruce, pine, etc., on the top, you may as well forget it, for they spell failure to any mechanical preparation you may contemplate. If they show up on the top, they will go on down to the bottom and the deposit may be passed up at once.)

Well, I got off the track again, but I wished to emphasize that root point, because I know of lots of promising projects nipped in the bud by roots.

If the brush be not too high, it may pay to grub this out, but as this usually has to be done by hand, the cost may increase your field operations considerably, so we assume the surface to be free of brush and covered with the usual growths which will indicate the nature of the peat for the top few inches or so.

Next, couple up three of Prof. Davis' sampling rods, with the sampler on end, and push them down—sampler at top end—till you reach bottom. If the peat is less than six feet deep, you will know it by the gritty feel when moving the rod slightly up and down. If sand or clay is found at a given depth, withdraw rods and insert in another place, sampler first. Take samples every foot till within 6 inches of where you know the sand or other subsoil to be, mix samples and put in sack for further treatment, this process to be repeated over a wide area, adding rods when required and noting depths at all soundings.

Take the samples thus obtained and run once thru an ordinary meat chopper, using a coarse grinding plate, then work up the mass between the hands till plastic. Then form into rectangular blocks of any length, or cross section. Do not make balls or lay in thin sheets; both of those will result in cracks, or uneven drying. Next, lay the rectangular strips (say 1½ inches square by 6 inches long) on wet blotting paper, upon a metal sheet, or on glass, and put in suitable place to dry.

After three days remove from the blotting paper and cord up. In four days more you may use artificial heat to hasten the drying preparatory to trying for ash content.

Of course, you can take the peat direct from swamp and dry out before maceration—then test for ash—but you will then only know its probable physical condition after sun and air drying on the surface of the swamp.

If the blocks, when made as noted above, crack when drying, it will be well to determine the cause and, as there are many reasons for this cracking, further investigation of the

physical make-up of the deposit and the subsequent mechanical treatment should be carefully gone into to determine if the raw material will permit of the treatment given, or if other methods of mechanical handling would attain better results.

The question of maceration is, to my mind, a very big one and must be determined solely by the nature of the deposit. Therefore, given an excellent deposit, an inferior fuel from a physical standpoint may spell failure unless the machinery be flexible enough to permit of changing the degree and extent of maceration to suit varying composition of the rare material. No one method of treatment will work on all peats, any more than we can mow hay with a subsoil plow.

Assuming that 50% of the failures of peat fuel projects can be traced to selection of unsuitable raw material and that the knowledge required embraces such studies as botany, chemistry, geology and an intelligent understanding of the functions of mechanical maceration, as distinct from nature's methods of obtaining the same end, and as the layman has not yet learned to differentiate between even peat and muck land, it would appear unfair to expect of him a diagnosis on a given deposit, which might involve the investment of thousands of dollars, where anyone familiar with the subject would have pointed out the chance of success, or otherwise, based on year of study of just such problems.

HERBERT GARNETT.

Minneapolis, Minn., May 22, 1920.

PEAT NITROGEN RESOURCES OF THE UNITED KINGDOM.

The following extracted from the Final Report of the Nitrogen Products Committee. deals mainly with the possibilities of obtaining adequate supplies of nitrogen from coal and other natural fuel resources.

Before the war, the United Kingdom produced and exported large quantities of ammonia nitrogen, but was a relatively small consumer of all forms of mixed nitrogen, depending, like Germany, upon imported products for all requirements in respect of nitrate and nitric nitrogen. At the outbreak of war, there were no nitrogen fixation processes in operation in this country capable of serving as a nucleus for rapid extension, as was the case in Germany, and during the war period, the United Kingdom, having command of the seas, has been in a position to depend upon overseas supplies.

The supremacy of the Chile nitrate industry is already being challenged, and the near future holds out the prospect that ammonium sulphate or synthetic nitrogen products may become the dominant factor in the nitrogen market and govern the price of nitrate instead of following it as hitherto.

The future of the by-product ammonia industry is closely bound up with the problem of fuel economy, and it must be noted that the potential reserve of ammonia nitrogen represented by the world's deposit of coal and peat are far in excess of the total nitrogen in the "caliche" deposit in Chile. It has long been recognized that the prosperity of industrial countries is essentially dependent upon the utilization of their fuel resources to the maximum advantage, and solutions of the questions are being sought in various directions. In general, the most promise is held out by method involving the treatment of fuel with by-product recovery, and the introduction and extensive development of such methods would lead to a notable increase in the production of ammonium sulphate. Their financial economy, however, will be effected to an important degree by the future demand for and market price of ammonia nitrogen, as is apparent from the foregoing observations.

Nitrogen from Peat.

It is estimated that the deposits of peat in the United Kingdom amount to not less than 5,000,000 tons, calculated as free from moisture, with an average nitrogen content of perhaps 1.5 per cent. (on the dry peat) although in the case of some bogs the figure is as high as 2.5 per cent. and over. The raw peat usually contains from 85 to 92 per cent. of water, and the problem of utilizing it on a really substantial scale for the recovery of nitrogen is only to be solved by devising a method, capable of continuous operation and independent of the climatic conditions, whereby the moisture content can be reduced to a workable value, say, of 50 per cent. or less, at a cost which will not render the entire process uneconomical.

When peat containing up to 50 per cent. moisture is treated in gas producers under ammonia recovery conditions, about 70 per cent. of its nitrogen content can be obtained in the form of ammonia or ammonium sulphate. Upon the bases of the average figure quoted above, the deposits in the United Kingdom thus represent a potential source of 50 million tons of combined nitrogen or 250 million tons of ammonium sulphate. Owing, however, to the character and low nitrogen content of some of the deposits and to other factors

such as inaccessibility, it is certain that considerable portions could never be economically utilized for nitrogen recovery.

Numerous attempts on substantial commercial scales have been made to obtain ammonia from peat, usually in conjunction with the production of power gas. Although some of these attempts have been attended with success under the conditions prevailing in the countries where they have been carried on, they have all been hampered by the difficulty of providing peat fuel in sufficient quantities to ensure the continuous operation of producer installations of even moderate capacity. The importance of this factor will be recognized when it is pointed out that the recovery of a ton of ammonium sulphate involves the excavation and treatment of from 90 to 400 tons of raw peat (according to its content of nitrogen and moisture), and the removal of from 63 to 360 tons of water from the raw material in order to render it suitable as a fuel for recovery producers.

The committee has devoted considerable attention to the prospects of utilizing peat either for nitrogen recovery alone or for the generation of electrical energy with by-product recovery as an auxiliary. The quantity of peat fuel required for the continuous operation of an installation of even moderate capacity is very substantial. The magnitude of the problem of providing the peat fuel required even by a single installation is apparent, and reliance upon natural air-drying of raw peat for its manufacture would seem to be out of the question when regard is paid to the climatic conditions prevailing in the United Kingdom. Of other processes hitherto proposed, the mechanical filtration of peat under pressure appears to hold out the best promise of success provided an economical method can be devised for rendering the raw peat amenable to filtration by partly or wholly destroying its colloidal nature. Notwithstanding the immense potential reserve of combined nitrogen in the peat deposits of the United Kingdom, there is no immediate prospect of it becoming a source of marketable products. In the present state of our knowledge, it is more economical to fix the nitrogen in the atmosphere than to recover the combined nitrogen existing in peat. (Through The Colliery Guardian, 1920. Vol. 119, p. 944.)

POWER FROM PEAT.

By A. R. Surface.

The high cost of fuel has again raised the question of utilizing to a greater extent the extensive deposits of peat in Ireland. The Government is at present considering the report of the committee which some time ago inquired into peat resources of the country.

In the meantime a Portadown concern has had some satisfactory results by utilizing peat in gas-producer plants for generating electric power to drive a weaving factory. The factory is driven by three Stockport gas engines, one rated at 150 and two at 120 boiler horse-power. They are single-cylinder engines driving the main shafting through ropes. The gas plant comprises gas generators, wet and dry scrubbers, tar extractors, fan and gas holders, and is supplied with peat as it comes from the bog by means of a transporter which delivers direct from the barge into the hopper of the generators.

According to a test made under ordinary factory conditions without any special preparations, the average indicated horse-power during a full working day of 10 hours, diagrams being taken every half-hour, was 277.4, and the amount of peat consumed, 7,712 lbs. This is equivalent to 2.78 lbs. per indicated horse-power hour, or, assuming 88%, mechanical efficiency, 3.16% lbs. per boiler horse-power hour. Allowing 3 cwt. for banking, the all-round consumption may be taken as 3.5 lbs. per boiler horse-power-hour, as an outside figure.

The peat used in the trial had on the average about 25% moisture. Mr. Parkinsson calculated that by handling large quantities, and employing every practicable labor-saving device, the peat can be won from the bog, dried, and delivered for a radius of five miles into a generating station at a price which would not exceed 0.28 pence per unit of electricity generated. He calculates that a modern steam turbine plant, operating at 160 pounds to 180 pounds pressure, 100 degrees Farenheit superheat, and 28-inch vacuum would, under similar conditions of load, cost 0.42 pence per unit, with coal at 35 shillings per ton, and that an anthracite gas plant would cost 0.36 pence per unit with anthracite at 45 shillings per ton. In addition, he points out that peat gas plants would probably be worked in conjunction with recover of by-products, the sale of which would further reduce the cost of power generated. (Scientific American, April 10, 1920.)

PEAT FIBER AND THE TEXTILE INDUSTRY.

Swedish efforts to introduce peat fiber as a substitute article in the textile industry has come to naught for the moment. It is the consensus of opinion that the prices for extracting the fiber from peat moss must be economical before it will ever come into general use. Two factories, one in Denmark and the other at Partille, near Goteborg, both established during the war for the purpose of utilizing peat fiber, have had to close their doors in recognition of this fact.

One of the leading exponents of the uses of peat fiber was Prof. Gustaf Sellergren, of Stockholm. It was upon his application that the Swedish Government recently caused an investigation regarding the possibilities of utilizing the vast deposits of peat moss in Sweden in the textile industry of the country. The experts appointed to make the investigation have completed their labors, and, among other things, found:

(1) Good textiles of peat fibre and "shoddy" can be manufactured and samples were demonstrated, but

(2) The Swedish peat mosses can produce only 100 kilos of fibers and moss per day, which is not sufficient for commercial purposes.

(3) The methods so far used in obtaining the fibers are too expensive.

The experts concluded by proposing that no further action be taken in the matter until the peat mosses could be examined carefully with regard to the amount of fiber contained, which work is within the province of the Swedish Committee on Geological Examinations and the Government's peat engineers serving in the Swedish Department of Agriculture.

Prof. Sellergren states, however, that his methods have not been tried, and that his patent rights for Sweden already have been sold. He claims to have some very fine samples of textiles made of peat fiber, and says that while his interest in this fiber has been cooled by the findings that some day he may return to the subject. He claims that Swedish peat mosses contain on an average 15 to 20 per cent peat fibers, and that it should be utilized in connection with the fabrication of peat litter.—(Consular Report.)

CO-OPERATIVE PEAT PRODUCTION IN GERMANY.

As indicative of the community co-operative movement which has developed in late years in Germany, the German press calls attention to the organization of a society among 35

towns in Thuringia for the purchase and development of peat beds lying in the Weser Basin, south of Bremen. These peat beds will be developed as a source of fuel supply for the towns in the association.—(Consular Report.)

HYSTERESIS OF AQUEOUS SOLUTIONS OF PEAT SOIL.

H. Puchner.

A clear, dark yellow solution is obtained by treating peat with cold water, and at the same time a faintly acid aromatic odor is noted. The solution has an acid reaction and on keeping deposits a slimy brown substance, and the solution becomes alkaline. The deposit obtained from the solution obtained from 50 grms. of peat amounts to 0.490 grm., and on incinerating leaves a residue of 0.218 grm. The ignited residue obtained alumina, ferric oxide, manganese oxides, lime, magnesia, and alkalis, sulphate, phosphate, and silicate. Microscopical examination of the peat deposit and the solution showed that on keeping changes occurred in their appearance, notably the formation of crystals. The clear solution after sedimentation contains gels of silicic acid, ferric hydroxide, and alumina.—(Kolloid-Zeits, 1919, Vol. 25, p. 196.)

PEAT ASH.

N. Van der Sleen.

Results of an analysis of peat ash made for the Harlem Machine Works of Harlem, Holland:

Organic (combustible matter)	20.04	per cent.
Inorganic (non-combustible matter)	79.96	per cent.

The composition of the inorganic contents, insoluble in acids, was:

Sand, etc.	68.12	per cent.
Calcium Sulphate	21.76	per cent.
Iron Oxide	7.85	per cent.
Magnesium Oxide	0.96	per cent.
Manganese Oxide	0.008	per cent.
Alkali (as K0H)	0.024	per cent.
Phosphoric Acid	trace.	

The original ash gave a solubility in water of 1.667 per cent., as follows:

Organic Matter	0.097	per cent.
Lime	0.656	per cent.

Magnesia	slight trace.
Sulphate	0.758 per cent.
Chlorine	0.021 per cent.
Nitric Acid	none.
Nitrous Acid	none.
Free Ammonia	trace.
Alkali (as K0H)	0.024 per cent.

It is concluded that the ash is of no value for manufacturing lye for soap, or as a fertilizer.—(Bruinkool, 1918, No. 7, p. 1.)

PEAT ASHES AS FERTILIZER.

Experiments were made in a special furnace, constructed for this purpose, upon samples of air-dried peat, of an average weight of 25 kilograms, from four different localities. The percentage of ash was as follows:

(a) Carisborg, Holland	4.0 per cent.
(b) Graetheide, Holland	7.3 per cent.
(c) Energie, Holland	7.0 per cent.
(d) Heerlerheide, Holland	4.5 per cent.

Analyses of the ashes were as follows:

	a.	b.	c.	d.
Phosphorous	0.0	0.0	0.0	trace
Nitrogen	0.04	0.06	0.04	0.07
Lime	0.10	0.07	0.11	0.16
Sulphur	16.17	14.2	8.8	16.0

—(Bruinkool, 1919, No. 12, p. 15.)

ACTION OF VARIOUS FERTILIZERS MADE FROM PEAT.

B. Tacke.

For these experiments a special fertilizer was used made from peat and containing ferric salts. Its analysis was: Mineral matter 10 per cent, nitrogen 1.5 per cent, lime 12 per cent, potash 0.6 per cent, phosphate 0.5 per cent. Another fertilizer used was humus silicic acid, which had the following composition: Mineral matter 30 per cent, nitrogen 0.9 per cent, lime 1.5 per cent, potash 0.3 per cent, phosphate 0.2 per cent. Pot cultures of oats in sand were used, to which were added potassium phosphate, calcium carbonate, and one of the special fertilizers. The crops obtained were poor, as also were those obtained in peat cultures. The peat fertilizers did not appear to have provided any nitrogen for the use of the plants. —(Bied. Zentr., 1919, Vol. 48, p. 289.)

DANISH PEAT SOCIETY.

The wave of patriotic feeling which swept over Denmark after the disastrous war of 1864, when North Schleswig passed into the hands of Germany, was the primary cause of the formation of the Danish Peat Society. Through the initiative of Colonel E. M. Dalgas a scheme was prepared in 1866 for the reclamation of the uncultivated land in Jutland. Thousands of people came forward to support the scheme, and subscriptions and donations were given by many communal authorities, saving banks, joint stock companies, and other bodies. Subsequently the Danish Government recognized in a practical manner the valuable work done by the Society, and since 1885 State grants have been made towards the cost of making plantations. The Society has become an agent of the State, and large sums of public money are administered by it. In 1918 State grants amounted to 2,102,856 kr. (about $500,000), whilst subscriptions from members, who now number 9,416, amounted ot 47,991 kr. (about $12,000).

The object of the Society is to encourage the cultivation of peat land in Denmark, and although this has been done mainly by instruction, the Society has also embarked directly on many and varied projects. The first and most important was the acquisition of land on its own behalf. Wherever possible this land was prepared and cultivated with ordinary farm crops, but poor land was utilized for the laying out of plantations. Marshes were drained; dry land was irrigated; marl pits were opened in order to provide a plentiful supply of marl and lime for improving the soil; and the transport necessary for the opening up of large areas was provided by the construction of light railways. Later still came the distribution of young plants, at cheap rates, to small holders and farmers.

The Society's field of action, formerly confined to Jutland, now extends over the whole of Denmark. In Jutland alone there existed in 1860 an area of about 2,900 square miles of uncultivated land, either heath or marsh. This area has now been reduced by more than one-half, mainly owing to the work of the Society, though the Danish Government has assisted by the laying out of State plantations.

The number of plantations now under the direction of the Society is 2,232, covering an area of about 195,000 acres. The problem of utilizing the wood thus grown was solved in certain cases by the installation of charcoal burning plant, and

by the extraction of tar. A considerable trade has also been developed in supplying fence poles and other forms of light timber. Large numbers of young trees, coniferous and deciduous, have been grown on the various plantations, and for a number of years between ten and twelve million plats have been distributed annually.

The search for marl was one of the early labors of the Society, as it was recognized that large areas would require some form of manure to render the soil fertile and the transport of this by light railway was begun in 1875. The subsequent expansion by the Society of the system of movable light railways was of importance. Up to the end of 1915 the amount of marl transported was about 1,300,000 tons, and the amount of lime about 160,000 tons.

The drainage and cultivation of marsh land took an important place among the activities of the Society. Irrigation canals were made, drainage systems were evolved, embankments and dikes were constructed, and plans and assistance given to a large number of farmers. About 270 miles of irrigation canals have been made for the improvement of about 17,500 acres of land. Extensive schemes of drainage have been put into operation, and the construction of embankments protects large areas from becoming useless stretches of water-stations and of the three large permanent experimental stations has enabled the Society to maintain this important work. From these stations are issued large numbers of plans and instructions for the benefit of small holders who are in a position to carry out improvements on their own behalf.

In the success of the Society's work the co-operation of the individual owner or occupier of the heath land has been fostered to a large extent by the educational system obtaining in Denmark. which aims primarily at implanting a love of rural life in the minds of the young. Subsequent training in the advanced school tends further to develop a taste for those agricultural pursuits which demand a full measure of the national traits of thrift, industry and neighborliness. (Through Journal of the Ministry of Agriculture—1920, Vol. 27, p. 85).

THE CULTIVATION OF WADFAST MOOR, ENGLAND.

Wadfast Moor is situated near Launceston, Cornwall, about 500 ft. above sea level. During the last 100 years the land has fallen out of cultivation, and it is now covered with

heather, gorse, sedges, rushes, and various forms of marshland vegetation. In places it is badly waterlogged. The surface soil is mainly a dark-colored loam from 5 to 8 in. deep, which rests on a subsoil of yellow clay. It is very sour and was found on analysis to contain a high percentage of organic matter, but relatively small amounts of available phosphate.

With a view to testing the possibility of growing oats on this type of land, the Cornwall Executive Committee decided, in 1918, to break up about 80 acres. Ploughing was commenced on 16th July, with Titan and Mogul Tractors and Davey-Sleep 2 furrow balance ploughs. At first an attempt was made to plough up and down the slope to facilitate drainage, but, owing to the tough nature of the turf and the rank herbage, the plough failed to turn the furrow. It was decided, therefore, to plough across the slope, commencing at the bottom. The furrows, which were about 11 inches wide, and 6 to 7 in. deep, were all turned one way, to ensure the complete inversion of the sod.

The difficulty of securing adequate drainage was surmounted by using a Case Road Grader imported from the United States. This implement is widely used in the United States and the Dominions and was found quite effective for making open drains. It may also be usefully employed in cleaning out existing open drains and ditches.

After ploughing, the road was rolled twice, in order to insure that the herbage should remain buried as far as possible. It was then twice disc-harrowed.

At this stage the land was allowed to lie fallow for 9 months until the following April, receiving no treatment except an application of lime at the rate of 1½ tons per acre. It was then again disc-harrowed twice with a Fordson tractor. The committee decided to try seven different kinds of oats, a plot being set aside for each kind. Each plot was divided into three sections, in order that manurial tests could be made at the same time. The first section was manured with a mixture of 5 cwt. superphosphate and 1 cwt. sulphate of ammonia per acre (mixture "A"); the second with 3 cwt. superphosphate and 1 cwt. sulphate of potash per acre (mixture "B"); and the third was left unmanured.

Sowing was carried out during the middle of May, at the rate of about 4 bush. per acre; this was rather late, owing to wet weather and difficulty in obtaining seed. The seven varieties sown were Victory, Golden Rain, Potato, Yielder, White Canadian Banner, Cornish, and American Black Tartar,

the last three being obtained from local sources. Yielder and Golden Rain gave the best crops, followed by Victory and Potato. Yielder, however, had the advantage of being the first seed to be planted, while Potato was planted last. The Cornish varieties were all very late in maturing, and, moreover, did not give very heavy yields.

As regards the effect of manuring "A" mixture gave the best results, possibly owing to the effect of the sulphate of ammonia, which enabled the crop to make a good start before the dry weather set in. "B" mixture gave fair results, the straw being of good length, but the crop was neither so thick on the ground nor so heavy in the ear as is the case of the "A" mixture plots. The unmanured sections in every case gave poor results.

It is interesting to note that although, as a general rule, the application of lime in Cornwall is supposed to have a harmful effect on oats, yet in these experiments no injury seems to have been caused to the crop, where lime was used in conjunction with other manures. In the sections which were limed, but otherwise unmanured, the oat crop was a total failure. As, however, the action of lime is slow-working in its effects, it is probable that the beneficial results of the liming would be noticed more in the 1920 season.

The results of the experiment seem to point to the value of certain early maturing varieties such as Yielder and Golden Rain for sowing in late districts, and further to the importance under such conditions of artificial manures, particularly superphosphate mixed with some sulphate of ammonia, for stimulating and hastening maturity.

The above experiment was initiated and supervised by Mr. Charles Nairn, Honorary Tractor Representative for Cornwall, and there is included in this account information communicated to the Ministry by Mr. W. Borlase, County Organizer.—(The Journal of the Ministry of Agriclutire 1920, Vol. 27, p. 9.)

THE IMPROVEMENT AND IRRIGATION REQUIREMENT OF WILD MEADOW AND TULE LAND.

The work herein reported is a phase of the Oregon Soil and Soil Water Investigations carried on in co-operation with the U. S. Department of Agriculture.

The wild meadow and tule lands of Eastern Oregon total over 515,000 acres, of which 355,000 acres are wild meadow

land and 160,000 acres are tule land. The wild meadow lands comprise over one-third of the irrigated area of the State and the control of irrigation and drainage and the substitution of cultivated forage plants for the native grasses and tules will add a great deal to the forage production of Orgeon.

The chief vegetation on the peat swamps is tules and flags mingled with wire grass and sugar grass, while the chief meadow grasses are redtop, bluejoint, wire grass, and wild clovers. The chief soil types are silt loam and peat. These swamp lands are irrigated by wild flooding from sloughs and canals led along the contour lines. The water table is raised and sheet water is kept on the surface until a short time before harvest, when part of it is removed by a crude system of drainage. The substitution of the strip-border method of irrigation and the installation of proper drainage will increase the productiveness of the large areas of these lands and will make possible the substitution of more productive tame grasses and legumes than for the wild grasses.

The average monthly precipitation for the summer months during the past five years has been slightly below normal. The temperature has been slightly higher than normal. The evaporation for the five summer months has averaged about 33 inches.

In the Chewaucan Basin alsike and timothy have yielded 3⅓ tons an acre as compared to ¾ ton of native grass on adjoining land. The most economical yields per acre inch have been obtained with 12 inches of irrigation water. The maximum yields have been obtained with about 18 inches.

Alfalfa in Harney Basin has produced about 2 tons an acre, while native wild hay has averaged but ½ ton an acre. At the Harney Valley Branch Experiment Station 6 to 10 inches depth of irrigation has given the best results with row crops. Field peas and grain have done best with 8 to 12 inches, while with alfalfa the best results have been secured with 18 inches.

In the Klamath Basin a duty of 12 inches has been found most profitable when the soil is saturated in the spring. Large areas of swamp lands in this section can be reclaimed at a moderate cost. In the Fort Klamath country the substitution of alsike clover and timothy for the native grasses has more than doubled the production of forage.

The results of the past five years show that an average depth of 18 inches of water on the field could produce the maximum yield now obtained. An average of 12 inches has

given the largest yield per acre inch. The average water cost of dry matter under good conditions for alsike and timothy has been 600 pounds. The water cost for wild hay has averaged 1,000 pounds and over. The coarse swamp vegetation can be replaced by pasturing and mowing, or by carefully burning off when the ground is still wet.

Oats and field peas are suitable crops for the first year or two after reclamation; later permanent alsike and timothy can be established. Cn new land a moist, firm seed bed and inoculated clover seed are essential. The double corrugated roller is a good tool for firming peat soil. Rye, sweet clover, and copious irrigation following drainage help to reclaim alkali spots. Gypsum or sulphur aids solution and removal of black alkali.

The strip-border method of irrigation has been found the most successful. Sub-irrigating from field ditches has been successful on medium and shallow peat when underlaid with a retentive subsoil.

Barnyard manure has given a good increase on shallow peat soils. Marked increases have been secured from application of sulphur to alfalfa on swamp borders.—(W. L. Powers and W. W. Johnston, Ore. Agr. Sta. Bul. 167.)

PEAT IN IRELAND.

According to the "Electrical Review," it has been calculated that the peat fuel supply available in Ireland is equal to about 2,000,000,000 tons of coal. One of the drawbacks to the industry—apart from the several inherent ones—is the fact that the peat must be cut by spade, one at a time, which is slow and laborious work. Recently attempts have been made to invent peat-cutting machines, which would greatly speed up production and lessen cost and bring the industry within the limits of profitable commerce. It is understood that these attempts have taken tangible form, and that at least one peat-cutting machine is now in operation.

PEAT DEHYDRATION.

Chas. Bouillon.

In order to remove the water from peat, it is partially air-dried and pulverized. The pulverized peat, which still contains considerable moisture, is brought in contact with a solution of calcium chloride, which gives it the property of coagulating blood.

(Can. Pat. 195,549, Dec. 30, 1919.)

PEAT DRIER.

W. S. Jackson. (U. S. P. 1,334,495.)

This patent is identical with Canadian Patent 185,779, described in this Journal, Vol. 13, p. 86.

PEAT FUEL.

K. E. Edgeworth.

The moisture is extracted from wet carbonized peat by introducing the same above 100° C. into a container. This closed container is provided with a perforated pipe, around which is a porous heat resisting filtering cone. A pressure of about 600 pounds per square inch is exerted, which is sufficient to prevent the formation of steam at 100° C. By this method the moisture is forced through the porous filtering material. The pressure is suddenly released, whereby steam is generated in the mass of filtered peat, thereby causing same to disintegrate. See also this Journal, Vol. 12, p. 102.

(Can. Pat. 198,137, March 9, 1920.)

DAMP PEAT FOR PRODUCER GAS.

S. C. Davidson.

The moisture in peat as taken from the bog cannot be reduced by mechanical pressure below about 65 per cent without losing large quantities of valuable organic matter along with the expressed moisture. If, however, the peat is thoroughly mixed to a putty-like mass with enough lime to render the mixture distinctly alkaline, say 5 per cent, the oily and resinous matter is coagulated, and the water may be reduced to 30-35 per cent by mechanical means.

(Br. Pat. 135,348, Dec. 23, 1918.)

WET CARBONIZING.

N. Testrup.

The wet carbonization of peat and similar materials is facilitated by using acids recovered in the process of evaporation of the liquid from the treated material. The peat may be wet-carbonized in vessels of or lined with resistant materials, with addition of acid, at the lowest and most economical temperature. The wet-carbonized material is forced through a filter-press or similar apparatus, the effluent evaporated and the acid recovered from the steam, or left in the

evaporator residue, is added to a fresh charge of peat. The evaporating-apparatus used is preferably that of a film evaporator; the vapors from the evaporating chamber have their acids recovered, and the residual matter is returned to the reverse side of the heat-transmitting partition of the evaporator to be used as a heating-means.

(Br. Pat. 135,578, Nov. 25, 1918.)

PEAT BRIQUETTES.

A. Pfisterer.

Peat, humus or the like is dehydrated by means of cloth-covered press rollers and mixed in a spiral mixer with a meal prepared from weeds or substances containing lichenin. The meal absorbs water readily, and the mass becomes so stiff that it can easily be pressed into briquettes.

(Ger. Pat. 313,892, May 19, 1918.

AMMONIA, GAS AND COKE FROM PEAT.

F. Sauer.

Dried peat or the like is heated in a shaft furnace so arranged that decomposition is effected in three separate zones. A mixture of air and steam is led in both at the top and bottom of the upper zone, which contains the fresh peat, and the ammonia generated is led from the middle of the zone; the material passes slowly down through the middle neutral zone into the lower zone, and the combustible gas produced in the lower zone is led away through a separate outlet. The pressure of the mixture of air and steam led into the upper zone is regulated by the pressure of gas escaping from the lower zone.

(Ger. Pat. 314,015, Feb. 18, 1913.)

DISTILLATION OF PEAT.

C. Francke.

Peat or other material is heated in slowly-revolving drums provided at the sides with tubes for leading to and away from the drums. The material is first dehydrated and then distilled at temperatures up to 550° C. The drums are heated from below by gas arising from the distillation, after treatment for the recovery of condensable products. Material containing 35 per cent of water can be treated in two hours.

(Ger. Pat. 314,337, Nov. 2, 1917.)

AMERICAN PEAT SOCIETY

Application for Membership

Mr. Chas. Knap, Secretary,
American Peat Society,
17 Battery Place,
New York, City.

Dear Sir:—

I, the undersigned, being interested in the development of our peat resources and in the welfare of the peat Society, beg to make application to membership in your Society, for which I enclose $5.00 as annual dues.

Signed ....

Address ....

....

CONTENTS

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Communications or contributions should be addressed to the Publication Manager or to the Editor, Herbert Philipp, 1 and 3 Peace St., New Brunswick, N. J.

EDITOR'S RESIGNATION.

On account of the increased amount of work falling on the shoulders of the present Editor, he has found it necessary to give up the editorial work connected with the Journal. The work this year has been carried through under great hardship on account of the large amount of time he has had to sacrifice in editing the Journal.

On July 27th, the Executive Committee accepted the resignation of the present Editor and appointed Mr. Clarence C. Osbon, of Ponca City, Okla., as Editor of the Journal.

Mr. C. C. Osbon needs no introduction to our readers, who will remember that he was formerly with the U. S. Geological Survey as their Peat Expert, and his work in this direction was so masterful and careful, that there can be no doubt that the Journals of the future will be well edited, and superior to what has gone before.

Your present Editor regrets very much that he has to give up this work, as he has always enjoyed it and feels well repaid by the cordial and pleasant relations with all the members of the Society, with whom he has come in contact, and also the large number of letters, not only from this continent, but from all parts of the world appreciating and supporting the work of the Journal.

The pleasant relations which have always existed between the Editor and the Executive Committee has made the work a pleasure and added incentive to the duties incurred. Furthermore the splendid work done by Mr. E. J. Tippett, in printing the Journal, is deserving of praiseworthy comment, and his attention in doing this work has considerably contributed to the peace of mind of the Editor.

The Editor has a good chance to see the work of the Secretary of the Society, which contributes largely to the success and spirit which exists among its members. Mr. Chas. Knap is principally responsible for the increased success of the Society since he has been in his present office, and your retiring Editor feels it certainly an honor to have been constantly in touch with him during his time.

The January, 1920, issue will be edited by Mr. C. C. Osbon, and while your present Editor still has a chance, he wishes to express to all its readers appreciation of their kind comments, which they have made from time to time, and feels sure that they will have no reason to regret the change which is now being made.

HERBERT PHILIPP.

Journal of the
American Peat Society

Vol. XIII JULY, 1920. No. 3

NOTE.

The publication of articles in the Journal of the American Peat Society is not an endorsement of the same by the Society or its officers. The American Peat Society is not responsible for the statements and opinions advanced by authors or correspondents. Written discussions on articles appearing in the Journal are invited. Correspondents and articles regarding peat and cognate subjects solicited.

TREASURER'S REPORT.

The Annual Report of the Treasurer for the year ending June 30th, 1920, is herewith respectfully submitted.

The receipts are the largest in the history of the Society, exceeding by over 150% the average annual receipts ($459) from the organization of the Society, for the ten years prior to 1918. They also exceed by 30% the revenue of the previous twelve months (June 30, 1919), which was the largest up to that date. But the abnormal cost of publishing the April, 1920, Journal, due to the unusual number of pages of printed matter and illustrations, and a 27% raise in price for printing, brought the disbursements $161.18 above the receipts, and would have caused a deficit had it not been for the balance of $390.36 remaining over from June 30th, 1919, which has happily permitted the payment in full of all bills against the Society to date, leaving a balance of $229.18 in the Treasury, July 30, 1920.

(Signed) CHAS. KNAP,
Secretary-Treasurer.

SUMMARY FOR YEAR ENDING JUNE 30, 1920.

Receipts.

Dues from members		$ 760.62
Journals sold		379.52
Advertisements		48.30
Cash on hand July 30, 1919		390.36
		$1,578.80

Disbursements.

Printing and Mailing of Journals—		
July	$111.83	
October	138.52	
January	185.02	
April	491.22	
		$ 926.59
Electrotypes		20.80
Editor's Expenses		247.04
Postage		20.10
Stationery		25.00
Clipping Bureau		24.00
Typewriting		26.39
Bank collection charges		6.95
Miscellaneous		2.75
*Legal expenses		50.00
Cash on hand June 30th, 1919		229.18
		$1,578.80

*In connection with Bill passed by New York Legislature prohibiting use of peat or humus in mixed feeds for cattle.

PEAT AS A FUEL.

The scarcity of fuel all over the world during the last few years has stimulated considerable interest in the peat deposits, not only in this country, but all over the world. Prof. Purcell's report on "The Peat Resources of Ireland," which appears in this issue, will therefore be read with considerable interest.

There have been periodical waves of interest in the development of peat fuel in this country, which have, as a rule, been stimulated by enthusiasts who have believed that they have discovered some new and profitable method for the preparation of peat fuel. In some cases the excavation and drainage of peat has been added as a secondary inducement to the adoption of their scheme; but as a rule the real interest has centered around novel proposals of an inventor or enthusiast, and with the failure to reach practical success, all interest in peat fuel has lapsed until a new enthusiast was born.

The present revived interest in peat fuel is associated not only with the general scarcity of coal, but with the great and apparent permanent increase in the cost of coal. Therefore the present interest is bound to become more stable and more definite knowledge is available to tackle this problem than has been in existence heretofore. Unlike coal fields, no shafts or underground workings are required for the excavation of raw peat; on the other hand, the whole surface for the full depth of the deposit has to be worked over, and every ton of dry peat obtained involves the handling once or oftener of at least 10 tons of raw material.

The relatively small amount of peat fuel won by hand digging is all right for individuals to cover their own modest requirements, but larger schemes for the use of peat fuel on an industrial scale involves the production of many thousands of tons of air-dried peat at a single deposit. This is the serious question to be solved in building up a peat fuel industry, whilst the labor problem also offers difficulty, as the majority of deposits are distant from social centers. The engineer will have to solve these problems, and they call fo rcareful consideration and experimentation, as the difficulties involved are by no means small.

PEAT NITROGEN AS PLANT FOOD.

Nitrogen is the most important plant food. It occurs in the soil in an organic form, but to be utilized it must first be changed into nitric nitrogen. The necessary decomposition

of organic matter depends on many factors, one of the most important of which is a sufficient supply of air. Large quantities of oxygen are used in decomposition reactions, so that the better the soil is areated, the more efficient is the decomposition of the organic matter, and consequently, nitrification. The amount of oxygen available also depends on the activity of the soil fungi which makes the phosphates and potassium assimilable. Reduction of nitrogen may occur in sufficiently moist soil, although it has not received carbon containing matter. This is attributed to insufficient aeration which causes the soil bacteria to reduce the nitric nitrogen. Formerly it was attributed to the presence of cellulose in the form of straw, etc., in the soil. This theory has been finally disapproved through a series of experiments conducted by the International Agricultural Institute.

THE PEAT RESOURCES OF IRELAND.*

By Pierce F. Purcell.**

Introduction.

The peat deposits, or bogs as they are more commonly called, cover oven one-seventh of the area of Ireland. For centuries they have provided fuel for the majority of the agricultural population and have been utilized to a very large extent for domestic purposes. The important contribution which the bogs make to the fuel problem in the West of Ireland is not generally appreciated. The West is deficient in timber, there is a complete lack of native coal, and the damp climate renders a plentiful supply of fuel a necessity. This the people have, and, generally speaking, within easy reach of their homes, so that the low calorific value and bulky nature of the peat is readily counterbalanced by its proximity and cheapness. The use of the peat has been almost entirely confined to domestic purposes, and there has been only a very limited amount of peat employed in industry.

Although 98 per cent of our coal is imported, we have none the less enjoyed comparatively low prices for coal in our seaport towns, and a glance at the map will show that the principal towns and a very large percentage of the population live on or very close to the sea-board. Before the war cheap sea freights were obtainable, so that a large quantity of our imported coal was delivered to the consumer at a price

*Read before the Royal Dublin Society, Mar. 5, 1919.
**Professor University College, Dublin, Ireland.

little, if anything, higher than that ruling in many towns in Great Britain. Previous to 1914 the coal used for domestic purposes in Dublin was to be had at little more than 20s. per ton, whereas in London it cost 21s. per ton. The average cost of the coal used for the production of electrical energy for tramway and lighting purposes in Dublin and Belfast was obtained at as low a figure as 9s. to 10s. per ton.

War conditions have changed all this, and the introduction of shorter hours and increased wages for miners, coupled with decreased production, will have the effect of greatly increasing the price of coal. Even if no further alteration in rates of pay or hours of work be granted to the miners, in the opinion of those best able to judge, coal prices can never again touch or even approach those ruling previous to the war.

It may be said that the changed conditions which affect the cost of winning coal will also affect that of peat production, so that the new conditions will prove no more favorable to peat. This would be true if it were not possible to make greater advances in the method of winning peat than are open to us in the cost of coal. Recent attempts made in Canada and Germany in the application of mechanical methods to the winning of peat have shown that a considerable measure of success has been attained, and, so far as Ireland is concerned, we may take it that the conditions have now placed peat in a more favorable position to compete with coal.

In Canada the shortage of coal has also directed fresh attention to peat development, and in Sweden, which imports most of its fuel, a substantial bonus has been given by the Swedish Government to encourage the production of peat. It it therefore timely to examine the possibility of peat development in Ireland and particularly from an industrial standpoint. Before doing so, and in order that any present who have not had previous experience with peat may grasp the difficulties in the way of its production and utilization, I intend to touch briefly on some of the physical characteristics of peat which have a bearing on the problem of winning it.

You must first catch the hare before preparing the meal, and so with the peat, it must first be won, and won at such a price and in such a condition that its utilization will be an economic proposition.

Origin and Formation of Peat Deposits.

A few words on the origin and formation of the peat deposits may not be out of place here and may help to clear away some prevailing misconceptions.

Bogs have been formed under very widely different conditions, and any explanations put forward must take account of this fact. The common conditions are deficient drainage, a plentiful rainfall, and also, generally speaking, moderately cool and humid climate. The damp atmosphere and copious rainfall of the West of Ireland presented favorable conditions for the formation of the extensive peat deposits.

The formation of peat is due to the accumulation of vegetable remains (usually below water level) at a greater rate than the rate of decomposition, so that the dead organic matter is preserved by the peaty acids produced by their partial decomposition, and once the formation of peat begins it goes on at an increasing rate. The chief peat-forming plants are reeds, cotton grasses, heather and the sphagnum mosses.

In the case of the great expanse of bogs in the Central Belt of Ireland we find a great plain lying between 200 to 300 feet above sea level with gentle slopes, and over a great part of it deficient drainage conditions exist. Soon after the glacial epoch innumerable shallow lakes were dotted over the central plain, held up between mounds and esker-ridges with pine and oak forests covering the dry parts. Flow through these lakes was sluggish, and their depth decreased gradually owing to the deposition of lime sediment until a depth of about 4 feet was reached, when reeds began to grow under conditions similar to those in the "fen" district in England, and in time the land surface was raised above the level of the water. This was sufficiently rich in lime and mineral content to support birch thickets, but with the gradual exhaustion of the mineral matter these were unable to survive and were followed by heather, cotton grass and lastly by sphagnum moss. The succession of plant life would therefore appear to have been influenced more by the variation in amount of surface water and lime, than by climatic changes.

Occurrence of Trees in Bogs.

In many bogs we find one or more layers in which roots and tree trunks occur, and this has given rise to the impression that the bogs were produced by the accumulation of leaves and branches from these trees. An excellent discussion on this subject by A. C. Forbes has been published in the "Clare Island Survey" papers by the Royal Irish Academy. Forbes states that these trees, usually pine or oak, only occur near the edges of the bog and close to the high ground. Let us suppose that the trees were growing in the dry ground near the bog or else on the surface of the bog near to the edge where it was shallow and dry, and that the drainage channel became blocked

and the water level raised for a sufficient length of time. The result would be that the trees would be killed and a new peat surface produced under conditions suitable for peat formation. Last summer during a visit to the "fen" country east of Ely I saw hundreds of trees which had been killed by the flooding of a large area of the country for nine months to a depth of some 6 feet due to the bursting of the banks of the Ouse. The soundness of this explanation is of almost vital importance for the future of peat winning by mechanical means, as should the bog contain much buried timber its mechanical dredging would be accompanied by great difficulty. It is generally believed that little timber is to be found in the middle part of the bogs in the central belt, and many borings made would appear to confirm this view.

Professor Cronshaw, of the University College, Galway, is at present investigating "the zoning of the Irish peat," and his work goes to show that the layers of peat in the bogs of the central belt occur in the same order, although thin seams of varying character occur here and there.

Physical Properties of the Peat.

Peat in an undrained bog contains anything from 90 per cent. to 95 per cent. of water, and this statement is equally true whether we are dealing with Irish peat or peat in other countries, with the exception of some deposits in Italy which are specially situated. By thoroughly draining the bog the water content may be reduced to some value between 91 per cent. and 88 per cent. We see, therefore, that the proportion of solids in the raw material will not exceed 9 to 12 per cent., and that the handling of such a low grade material must present a serious economic problem. I remember being much struck by the observation of my colleague, Professor Hugh Ryan, when he casually remarked that there was a greater percentage of solids in milk than of peat in a drained bog. On looking the matter up, I found that he was right, as cows' milk contains some 12 per cent. to 15 per cent. of solids compared with 9 per cent. to 12 per cent. for the drained bog. Strange as it may seem, little definite information exists as to the effects of drainage, although, as I hope to show, the difference in the figures mentioned may mean that between commercial success and failure.

The water content of peat may be stated in three ways, and as an illustration let us take the case of a peat containing 90 per cent. of water. We might state that the peat contained 90 per cent. of water which is the usual but the more misleading way, or else state that the peat contained 10 per cent. of

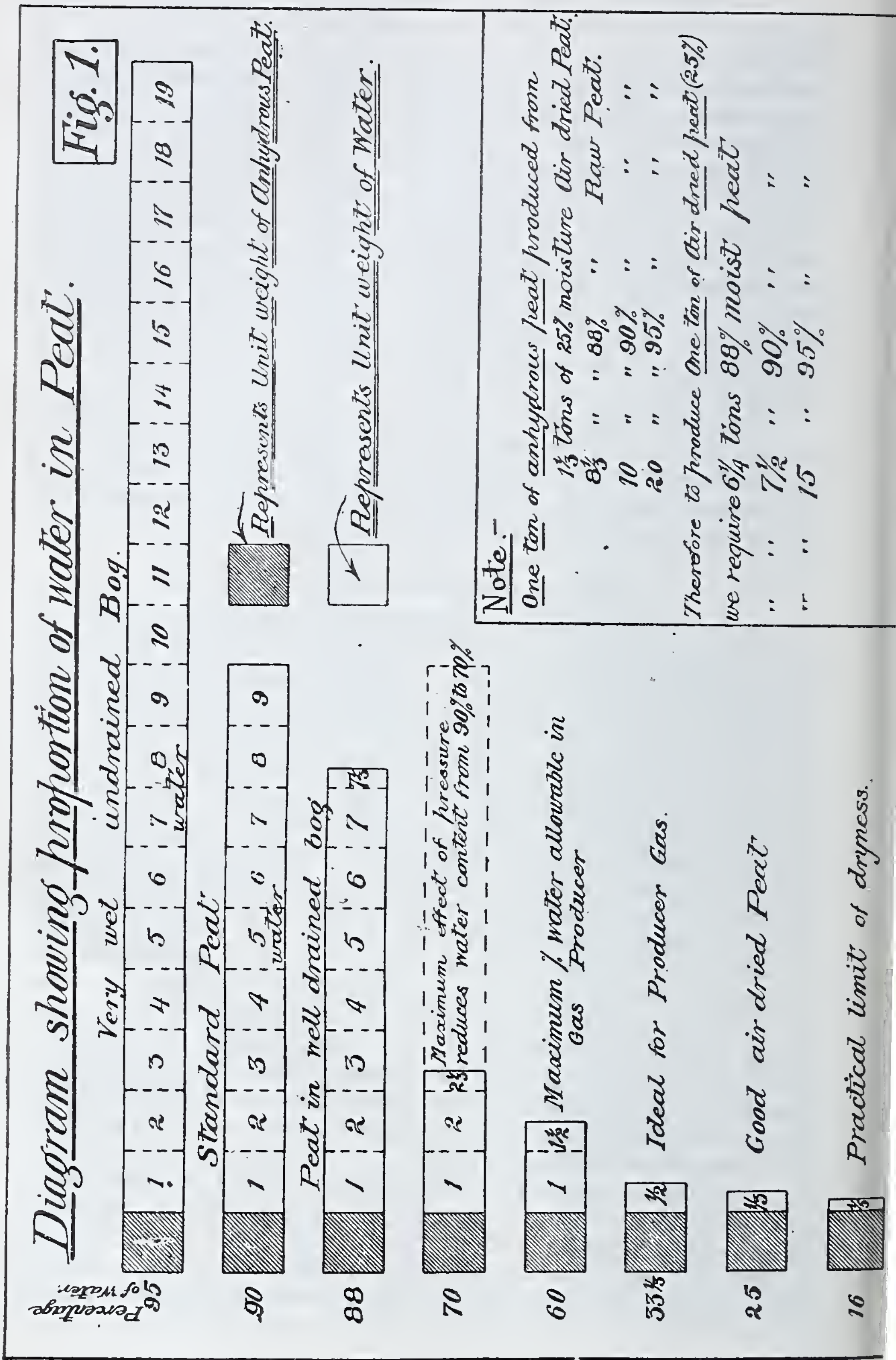

Fig. 1.
Diagram showing proportion of water in Peat.
Percentage of Water.
95 Very wet undrained Bog.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
water
90 Standard Peat
1 2 3 4 5 6 7 8 9
water
88 Peat in well drained bog
1 2 3 4 5 6 7 7⅓
70 Maximum effect of pressure reduces water content from 90% to 70%
1 2 2⅓
60 Maximum % water allowable in Gas Producer
1 1½
33⅓ Ideal for Producer Gas.
½
25 Good air dried Peat
⅓
16 Practical limit of dryness.
⅕
Represents Unit weight of Anhydrous Peat.
Represents Unit weight of Water.
Note.—
One ton of anhydrous peat produced from
1⅓ tons of 25% moisture Air dried Peat.
8⅓ " " 88% " Raw Peat.
10 " " 90% " "
20 " " 95% " "
Therefore to produce One ton of Air dried peat (25%)
we require 6¼ tons 88% moist peat
" " 7½ " 90% " "
" " 15 " 95% " "

anhydrous or dry peat substance, or we might state the "water ratio," that is, relative proportions of water to dry peat, which in this case, would be nine to one.

When we compare a peat with 95 per cent. of water to one with 90 per cent. of water at first glance it looks as if the difference were only slight, but if the statement were put that in the first case you had 5 per cent. of dry peat and in the second 10 per cent., or that the "water ratios" or the relative proportions of peat and water were 19 to 1 in the first and 9 to 1 in the second, it would be quite obvious that the second peat contained twice as much valuable matter as the first. A glance at the diagram (Fig. 1) will make this clear. The weight of anhydrous peat or dry peat substance present is assumed to be the same in each case, and is shown by a cross hatched square representing any unit of peat by weight, and the proportion of water is shown by the number of open squares so that the water ratio is seen by inspection. The advantage of stating the "water ratio" rather than the percentage of water will be seen from the example first quoted where we saw that an increase of 5 per cent. in the percentage of water 90 to 95) means that the relative amount of water is more than doubled, whereas if we reduced the water content from 33⅓ per cent. to 25 per cent. (water ratio .5 reduced to .33) the diagram shows that there is little difference in the **actual** amount of water present in the two cases although when stated as a percentage the difference seems considerable.

For the undrained bog I have taken 95 per cent. water (water ratio 19 to 1) as shown by the first column in Fig. 1. The second column which I call **standard peat** with 90 per cent. water, represents what may be considered the average condition of a well drained bog, and the third column with 88 per cent. would hold near the exposed face of a bog where the drainage conditions were exceptionally good. Peat cut by hand and air dried under normal conditions in this country should not contain more than 25 per cent. of water, and that has been taken as the standard for air-dried peat.

It will be seen from the diagram that to produce one ton of air-dried peat we must handle 15 tons of raw peat containing 95 per cent. of water; or 7½ tons of 90 per cent. moist peat, of 6¼ tons of 88 per cent. moisture peat. The cost of excavating, handling and spreading a ton or a cubic yard of peat with 95 per cent. water is just as much as that for the same quantity of one with 90 per cent., but in the latter case the yield of finished product is double that in the former. We see therefore that between working on a drained and an un-

drained bog may easily mean the difference between success and failure.

The remainder of the diagram shows the various stages through which peat passes from the drained bog to the finished air-dried product, the fourth column showing the maximum effect of pressure on raw peat. Even when a high pressuse is sustained for a long time the moisture content cannot be reduced below 70 per cent. In good weather with ordinary air-drying methods this condition may be reached in about 2 or 3 weeks and a further 5 or 6 days will reduce the moisture content to 60 per cent., which is the wettest peat that manufacturers of producer plant have **claimed** to be possible to use in a gas producer. Column 6 shows peat with 33⅓ per cent. water, which is generally considered ideal for the production of producer gas, and column 7 represents a good air-dried peat with 25 per cent. of water, which makes an excellent fuel for domestic purposes or for use in a steam boiler.

Even when all the water is driven out of the peat by the application of heat it rapidly takes up about 16 per cent. of miosture on exposure to the air, and hence this is the practical limit beyond which it is useless to dry peat. In the Swedish peat powder plants the peat is reduced to a lower moisture content than this but has to be stored in covered bins or silos.

The next diagram (Fig. 2) shows the calorific value of peat containing different percentages of water. On the left we have the number of British Thermal Units contained in one pound of peat, the B.T.U. being the amount of heat required to raise one pound of water 1° F. The calorific value of **anhydrous peat** varies with the percentage of ash and other constituents, but lies between 8,000 and 10,000 B.T.U. per pound.* In the diagram 9,500 B.T.U. has been taken as an average value for Irish peat. Take the case of a peat with 25 per cent. water. Here one pound of the peat fuel contains only

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*The following calorific values have been determined by Miss Phyllis Ryan, M.Sc., for peat samples collected by the author:—

Carrigaholt, Co. Clare, 10.200 B.T.U. per pound (anhydrous value) corresponding to 7,370 B.T.U. with 25 per cent. moisture.

Dartmoor, Devonshire. 10,700 B.T.U. per pound (anhydrous value) corresponding to 7,745 B.T.U. with 25 per cent. moisture.

Inverin, Co. Galway. 10.900 B.T.U. per pound (anhydrous value) corresponding to 7.895 B.T.U. with 25 per cent. moisture.

These values are very high and, as stated above, the average for air-dried peat in Ireland with 25 per cent. moisture should be about 6,850 B.T.U. per pound.

The density of raw peat in the bog may be taken as 1.00 and that of the air-dried "cut peat" from .17 to .75 depending on its quality, a fair average value being .5. Machine peat (macerated) has a density of .85 to 1.00 when air dried.

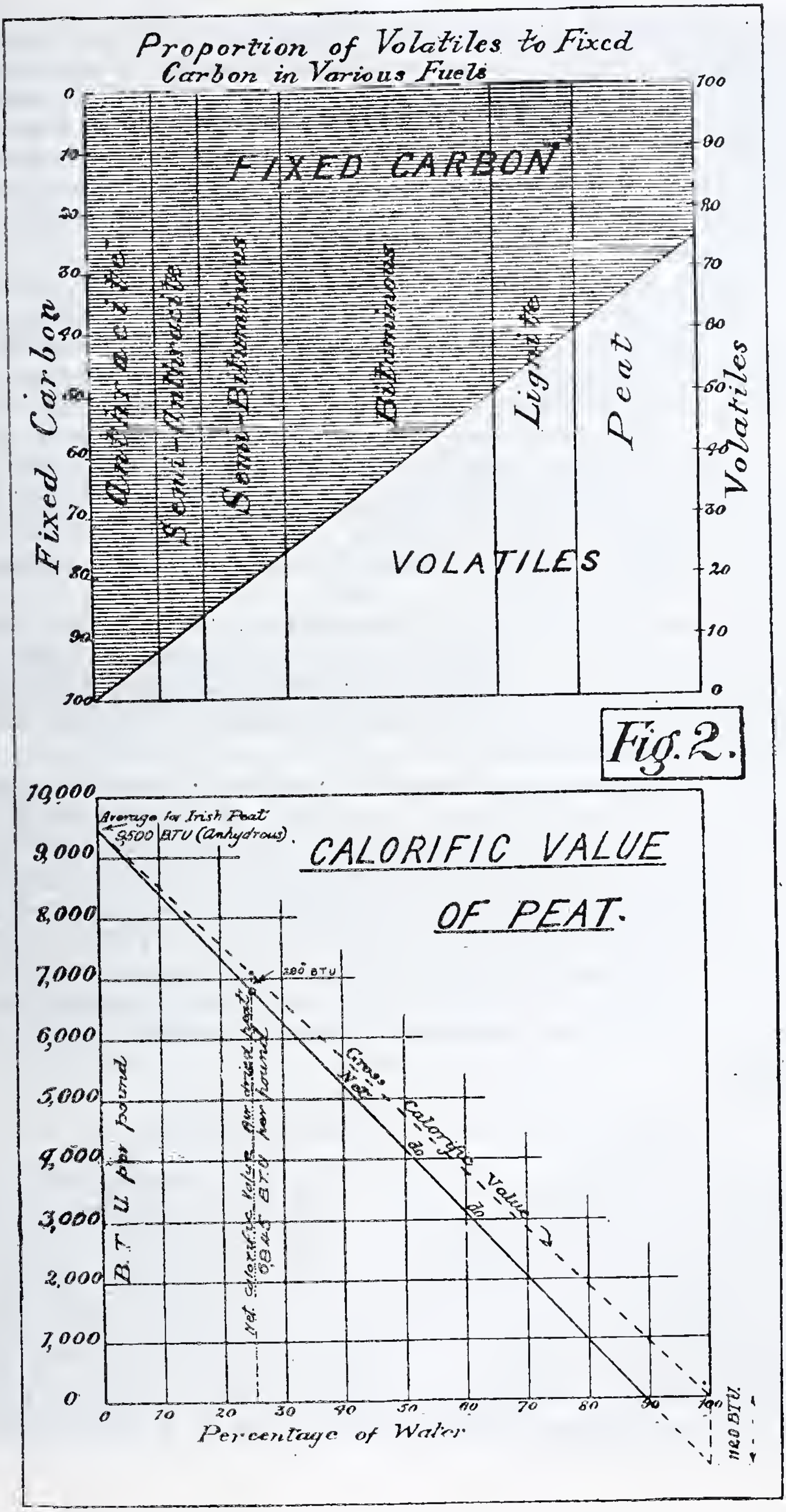

Proportion of Volatiles to Fixed Carbon in Various Fuels
FIXED CARBON
VOLATILES
Anthracite
Semi-Anthracite
Semi-Bituminous
Bituminous
Lignite
Peat
Fixed Carbon
Volatiles
CALORIFIC VALUE OF PEAT.
Average for Irish Peat 9500 BTU (Anhydrous)
B.T.U. per pound
Percentage of Water
Gross Calorific Value
Net
1120 BTU

Fig. 2.

three-quarters of a pound of dry peat and this can give off 7,125 B.T.U., but at the same time one-quarter of a pound of water has to be evaporated which requires 280 B.T.U., leaving the net calorific value 6,845 B.T.U. It will be seen from the diagram that with 89 per cent. of water the calorific value of the 11 per cent. of dry peat will be just sufficient to evaporate the 89 per cent. of water and that hence such peat has no net calorific value.

Taking air-dried peat with 25 per cent. water the average net calorific value as fired will be 6,000 to 7,000 B.T.U., and as coal used for industrial purposes gives from 12,000 to 14,000 B.T.U. per pound, we may take it that one ton of coal is the calorific equivalent of two tons of air-dried peat.

Fig. 2 also shows the proportion of fixed carbon to volatiles in the various fuels commencing with Anthracite coal and ending in peat, which may be said to be coal in the first stage of formation. In the case of Anthracite the carbon runs from 98 to 92 per cent., whereas for peat the fixed carbon is only 25 to 35 per cent.

The ash in Irish peat averages 4 per cent. of the anhydrous peat and is low, judged by American standards, and usually increases from the surface downwards owing to the increased humefication of the vegetable matter which has taken place in the lower layers.

The nitrogen will average 1.8 per cent., which compares favorably with that of other countries. It varies from 1 per cent. near the surface to 2.5 per cent. near the bottom in deep bogs. Where the recovery of ammonia in a producer gas plant is the **principal aim,** 100 lbs. of sulphate of ammonia should be recovered from each ton of air-dried peat. This is a very valuable by-product, the market price under normal conditions being about £11 per ton, and if the recovery of by-products is attempted it is most important that a bog with a high percentage of nitrogen should be selected.

The Elimination of Water from Peat.

Part of the water contained in peat is mechanically held and may be removed by pressure, but the remainder appears to be held by the colloidal matter in the peat so firmly that it cannot be removed by even very high pressures. Its complete removal can only be effected by evaporation, but a part of the remaining water may be pressed out after subjecting the peat to some process which alters its structure. The difficulty in removing water from peat has been ascribed by Ekenberg to the existence in the humefied peat of a complex gela-

tinous hydrocarbon compound called hydrocellulose. The hydrocellulose is stated by Ekenberg to be present to the extent of about 1 per cent., but his views are not generally accepted.

Many methods have been tried for the elimination of water from peat, but the most successful is drying by natural atmospheric agencies, wind and sunshine being the chief factors. This method has been practiced under one form or another since at least the commencement of the Christian era, and Pliny the elder observed it in operation whilst engaged in the then army of occupation in Germany. This makes it all the more surprising that notwithstanding the advance in science and in mechanical and industrial operations the air drying of peat by natural means is the only recognized commercially successful method in use today.

It has been said that the spreading of the raw peat on the wet surface of a saturated peat bog and leaving it in contact with what is roughly a 90 per cent. water surface and immersed in a layer of nearly saturated air is a very inefficient process. I agree, but the process costs little and at the moment I do not know of one which does the work at a less cost.

The best way to utilize the calorific energy of the peat, originally the product of the radiant heat of the sun, is to make use of the heat of the sun and its dynamic effects to dry the peat naturally as it is spread on the surface of the bog and not to waste the heat energy of the peat in evaporating the contained water.

When peat, as taken from the bog, is subjected to high and long continued pressure almost three quarters of the contained water is driven off and the moisture content is reduced from 90 per cent. to 70 per cent., but even in this condition it is still useless for fuel purposes. This represents the maximum effects of pressure on raw peat, and it is now accepted as a fact that peat fuel cannot be prepared by pressure alone.

From the diagram giving the calorific power of peat (9,500 B.T.U. anhydrous value) with different percentages of water it will be seen that if we have 100 per cent. efficiency in the evaporator or dryer, peat with 89.5 per cent. water could just be dried by burning the 10.5 per cent. of dry peat contained, and you would have no dry peat left, or, in other words, peat with 89.5 per cent. of water has no net calorific value.

When, however, we take account of the fact that the efficiency of the dryer will not average more than 60 per cent., it can be shown that peat with 83.5 per cent. of water has no practical calorific value, as the 16.5 per cent. of peat is required to evaporate the contained water.

The drying of peat by artificial heat does not become a

practical consideration until the moisture content has reached 70 per cent., and even then it is a very doubtful financial propcsition.

Let us assume that we have obtained peat with 70 per cent. water—then to derive 100 pounds of peat fuel, suitable for use in a gas producer (that is to say, containing 33⅓ per cent. moisture), from peat containing 70 per cent. we must burn 41 pounds of fuel similar to the final product to provide the necessary heat. Hence the yield of such a process will only be 59 per cent. of the dry peat dealt with, and even this calculation is based on a 60 per cent. efficiency in the dryer whereas in practice it may not exceed 50 per cent.

But we must remember that there are practical difficulties to be taken account of, such as the charing of the peat and the labor, maintenance and capital charges on the plant, so that it can hardly be economic to obtain the drier fuel at the expenditure of over 40 per cent. of the yield.

A system somewhat on the above lines is used at Orentano in Tuscany where about 45 to 50 tons of 33⅓ per cent. moisture is consumed every 24 hours in Mond producers. The exhaust heat of the gas engines, the heat from boiler chimney gas and the heat from producer gas specially burned in a preheater is used to dry the peat artificially so that the gas used for the actual production of powder is only equivalent to that from one-third of the peat originally taken. Such a scheme is only possible where the plant is worked mainly as a by-product plant and where cheap labor is available. (The raw peat is said to contain about 77 per cent. of moisture at Orentano.)

At Codigoro, also in Italy, a similar scheme is adopted for the artificial drying of peat, which in the raw condition contains less than 60 per cent. of moisture.

Apart altogether from the difficulty of drying the peat in contact with the wet surface and the humid air close to the bog and at a point where the wind velocity is small, there are other considerations which point to the desirability of obtaining some artificial process for drying the peat. The season during which peat dries is practically limited to that portion of the year during which evaporation exceeds the rate or rainfall. (This is not strictly correct as all the rain which falls on the peat is not absorbed but much of it runs off, as when humefied peat has reached a certain stage in drying a kind of waterproof skin or crust is formed which does not readily admit rain.) This period of excess evaporation does not usually exceed five or six months and runs from April to August inclusive. Other limitations exist in the form of frost which by freezing the water contained in the peat bursts the sods or

blocks so that they lose much of their substance. The short season for peat winning renders it necessary to produce in that season sufficient peat to last for the whole year, and it thus happens that a great number of hands are required for a portion of the year and few for the remainder. **This forms a serious obstacle, and it must be met if the peat industry is to be put on a permanent basis.**

It will therefore be seen that the foregoing considerations furnish a very strong incentive to inventors and others to produce some form of apparatus by which the peat may be dried artificially and the industry carried on for 12 months instead of during five or six. So far no one appears to have succeeded and even the Ekenberg process is still in the experimental stage.

Peat has been placed in centrifuges: electric currents, alternating and direct, have been passed through it, freezing has been tried and chemicals added, and although a certain amount of success has been claimed in laboratory experiments, the **economic** solution of the problem of artificially dehydrating peat seems to have baffled all.

To get over the objection of leaving the peat in contact with the wet surface of the bog various devices have been employed. In Carinthia poles about 10 feet long are driven into the bog to a depth of 4 feet and transverse spikes driven through the poles, on which the peat blocks are then stuck so that drying is accelerated. Timber trays with wooden laths have also been used and a sample of one is exhibited, but the depreciation and capital charges for such systems are very high.

Area and Fuel Content of the Irish Peat Deposits.

We are fortunate in having authentic information as to the area and depth of our Irish peat deposits and it is possible that Ireland possesses more exact data on this point than any other country. This is entirely due to the good work accomplished by the Bogs Commissioners appointed in 1809 "to inquire into the nature and extent of the several bogs in Ireland and the possibilities of draining and cultivating them." General Vallancey, the then head of the Great Ordnance Survey, acted as Chairman of the Commission, and the work carried out included a detailed survey of all bogs in Ireland whose area exceeded 500 Irish acres. Soundings were taken, plans and sections prepared and schemes of drainage and reclamation put forward after must careful consideration.

The reports were prepared by a very able panel of Engineers and Surveyors, amongst whom may be mentioned Rich-

ard Griffith (Junior), afterwards better known as Sir Richard Griffith, Chief Commissioner of Valuation, and Richard L. Edgeworth, of the famous Edgeworth family. The Commission published four reports during the years 1809 to 1814, and, on the completion of its labors, deposited all its documents and plans in the safe keeping of the Royal Dublin Society, from which they were transferred in 1877 to the National Library. The original MSS. maps may be seen there and they form excellent examples of the highly finished draughtsmanship which was a feature of those days. About £40,000 was spent on the work of the Commission and from the reports we learn that practically all the bogs in Ireland could be naturally drained and without any great expenditure.

The question of utilizing the bogs of Ireland has again been the subject of an Enquiry, and it was fortunate that another Griffith—this time Sir John Purser Griffith, a distinguished Engineer and a prominent member of this Society—was available to act as Chairman.

Table I. shows the area, depth and fuel content in millions of tons of anhydrous peat, and the figures are based on the data in the reports of the Bogs Commissioners.

Consumption of Peat in Ireland.

Some remarkable figures have been obtained by the Department, which shows that 62 per cent. of the farmsteads in the country are solely dependent on peat fuel. Allowing for a proportion of those who use a little coal, it may be said that two-thirds of the farming population of Ireland depend for their fuel supply on peat alone, and this would mean 1½ million people, and in addition there are considerable numbers in the country towns who use peat to a large extent.

The consumption of peat in Ireland must lie between 6 and 8 million tons per annum, and we import 4,650,000 tons of coal and raise about 90,000 tons of native coal. If we assume that one ton of coal is the calorific equivalent of two tons of peat, then the equivalent fuel supply required in Ireland is 8¼ million tons of coal or 16½ million tons of peat per annum. The figures in Table II. show that the possible life of the peat deposits is 200 years if no coal were used, and of the Irish coalfields 20 years, this, of course, assuming that only one kind of fuel is used and that no coal is imported. If, however, the present rate of consumption of native fuel were to continue the peat would last for some 500 years and the native coal more than twice that length of time.

Put in another way, the heat reserve contained in the peat bogs is more than 10 times that of our **proved** coalfields.

Peat Deposits of Other Countries.

Table III. gives the area of the peat deposits of the various countries according to the best information available. It is difficult to get any definite data about the British deposits, and it is doubtful if the figure is even approximately correct. There are large areas in Devon, Lincolnshire, Lancashire and Yorkshire, and also in Scotland. Later on I will indicate briefly the development of peat industry in these countries.

TABLE I.

Area and Fuel Content Irish Peat Deposits.

	Area, acres.	Average depth, feet.	Anhydrous peat contained, millions of tons.
Flat bogs in central belt.....	726,000	18.66	1,640
Flat bogs outside central belt	287,000	13.32	460
Flat bogs unsurveyed	635,000	10.0*	770
Mountain bogs	1,380 000	5.0*	830
Total..................	3,028,000	Total.....	3,700

This 3.700 million tons of anhydrous peat would be equivalent to 5,000 million tons of average air-dried peat fuel.

*Note.—Approximate depth assumed.

TABLE II.

Comparative Importance of the Peat and Coal Deposits of Ireland.

	Tons.	Tons.
Coal imported (average 1912-1914)..............	4 660 000	
Coal mined in Ireland	90.000	
Total coal used.......................		4,750,000
Peat consumption 7.000,000 tons, equivalent to 3,500,000 tons coal.......................		3,500,000
Equivalent fuel requirements of Ireland in terms of coal		8,250,000
*Estimated available coal in proved Irish coalfields.		175,000,000
Sufficient to supply country if no coal were imported and no peat used, for...............		20 years

	Tons.
Equivalent peat consumption if no coal were used..........	16,500,000
Estimated content of peat deposits......................	5,000,000,000
Possible life of peat deposits if no coal were used (allowing for waste, etc.)	200 years

*No account is taken of the possible coal in the new coalfields predicted at Lough Neagh, Ballycastle or Larne, borings for which are now being made.

TABLE III.

Areas of the Peat Deposits of the World.

Country.	Area in square miles.	Authority
Great Britain	9,400	Thorpe.
Ireland	4,700	Bog Commissioners.
United States	11,200	C. A. Davis.
Canada	37,000	E. Haanel.
Sweden	19,200	Wallgren.
	(2,000 sq. miles peat fuel bogs)	
Norway	2,900	Hausding.
Denmark	400	"
Germany	9,900	"
Austria	1,500	"
Russia	65,000	"
Finland	38,000	"

The Winning of Peat by Hand.

There is no need to enter into a lengthy discussion of the different methods of forming what is called "cut peat" or turf. It may be said to consist in cutting out from the bog blocks of peat weighing from 7 to 20 pounds and spreading these on the surface of the bog to dry, and when dried the blocks weigh from ¾ to 2 pounds. The form and size of the peat block varies in the different countries and is made to suit the local climatic conditions. For instance, on Dartmoor, in Devonshire, where the rainfall and humidity are high, the peat block is cut 2 feet long by 9 inches wide and from 1½ to 3 inches thick. In the early summer the block cut is 3 inches thick, but later in the season the thickness is reduced to 1½ inches to encourage quicker drying.

On Bodmin Moor, in Cornwall, they cut blocks of very fibrous peat 4 inches by 4 inches square and up to 3 feet 6 inches long resembling large bars of soap. These are placed in carts in which they are drawn out from the bog and spread to dry on the higher adjoining ground.

In Ireland at least 80 per cent. of the peat is cut with a "wing slane," a tool resembling somewhat a garden spade with the addition of a "lug" or "wing" at right angles to the bottom corner. This wing reduces the number of cuts to be made to detach the sod and the cuts are made in almost a vertical direction. For work on the small scale and where the object is to procure the annual supply for one or two households the wing slane method is economical. The peat when cut is thrown on to the bank and forked into rows for drying, or else it is cast to a catcher who places it in a particular way on a flat-

bottomed turf barrow on which it is wheeled out and tipped on the bog in rows or heaps.

The "**breast slane**" is not so largely used in Ireland as the "**wing slane**," but is widely employed in County Kildare to cut peat fuel for the supply of Dublin. It consists of a short-handled spade and is used to cut peat blocks whose longest axis lies in a horizontal direction in the bog. This has an advantage as the turves so cut are less friable and of better shape for packing on canal boats than the peat cut with the wing slane.

The peat cut by either of these methods is spread on the surface of the bog for a week or two, is then raised into small piles or "footings" so arranged that the wind passes freely through them, while at the same time the sods give each other mutual protection against rain. When a further stage in the drying has been attained the turves are "refooted" or made into small honeycombed clamps with plenty of free air spaces, and eventually when dried are placed in larger stacks from which they may be drawn home for use.

In the Midlands of England and in Somerset a square peat block 10 inches by 10 inches by 3 inches thick is cut and very neat methods are employed which attain a high degree of efficiency. It may be said that although the methods for hand-cutting peat differ in every district and in each country, that none the less each method, evolved as the result of continued practice for many years, has reached at least as high a state of perfection as is usual in industrial operations. After studying the methods and operations used by skilled operators in cutting peat in different places in Ireland and also in England, I came to the conclusion that if an expert in motion study had gone closely into the matter he would be able to effect little, if any, improvement in the matter of cutting, but the methods adopted for spreading the peat are open to question.

It must be borne in mind that the cutting, spreading, harvesting, collection and transport of the peat is a huge handling undertaking in which each step must be considered in relation to the whole if an economic result is to be attained. It has long been recognized that the method in use in Ireland by which a comparatively large quantity of peat is cut from one face or turf bank, while economic for small scale operations, is not so when used on the large scale.. Hodgson, writing in a paper read in 1863 before the Institution of Civil Engineers of Ireland, pointed out forcibly the uneconomic features of this method. They are in effect that you can only spread a certain amount of peat on each acre of bog surface, and therefore the more peat that is cut per lineal yard of cutting bank, that is

the deeper and wider the cut, the greater the distance out from the fact to which the peat must be spread. And it will then have to be collected from this distance. A little study will convince one that economy is to be had by cutting a small amount of peat per lineal yard of face and in increasing the number and length of the faces. That is the direction in which Dutch and other Continental methods have progressed. These methods can be seen in operation on four bog areas in Ireland, those of the Turraun Peat Works, near Ferbane, King's County, Irish Peat Industry, near Edenderry, Mr. Hamilton Robb's bog at Maghery south of Lough Neagh, and the Irish Peat Development Company, in the same district, and on the bogs of the United Kingdom Moss Litter Company, at Portglenone, County Londonderry. In all these cases the "cutter" who digs the peat spreads it directly on the surface of the bog on either side of him and no "catcher" or "wheeler" is required. He cuts a small slice 2 ft. by 2 ft. in section from each face, the length of the face being 100 yards.

For this system the whole bog must be systematically laid out and drained, and it takes some three to five years before the full effects of the drainage are secured. The bog is divided into a number of cutting fields or banks by the drain which are usually run about 10 to 12 yards apart. The harvesting and collection of the peat is carried out systematically so that narrow gauge tramway tracks with 30 cwt. wagons and electric haulage can be employed for its final removal.

It must be remarked that it is only on Mr. Hamilton Robb's bog, north of the Blackwater in County Tyrone, that the method of cutting just outlined is used for cutting peat fuel. In the other places mentioned it is used for moss litter peat alone.

In all hand-methods of winning peat the work of the "cutter" requires both skill and strength, whereas the "footing," turning and harvesting operations can be efficiently performed by women or children. The collection requires the carrying of heavy loads, and although these are often carried by women, it is really a man's task. The tasks requiring skilled and able-bodied labor as compared with light unskilled work roughly in the proportion of two to one, whereas with the mechanical methods of peat winning, to be described later, the proportions will be reversed and the total number of operatives required to win a given quantity of peat will be considerably reduced.

Another method by which "hand turf" or "mud turf" is produced was much used, but is now employed to a limited extent in County Cavan and adjoining districts.

The Mechanical Winning of Peat.

The peat fibres in the bog are arranged more or less in horizontal layers, and for the past 60 years it has been recognized that by macerating and mixing the raw peat, the fibres become more uniformly distributed through the mass. This causes a more uniform shrinkage and greater contraction to take place on drying and produces a denser and tougher fuel. Many forms of peat-macerating machines have been devised, some of which simply mix the peat to secure uniformity whilst others attempt the cutting and tearing of the fibres. The peat fed into a hopper is pushed through the body of the macerator by a single or double spiral screw. While being forced through the machine the peat is mixed and in some cases forced past rotating and fixed knves of different forms, as in the Anrep and Anderson machines.

The peat pulp is then forced through the mouthpiece in the form of one or more streams or bands of peat. Sometimes these bands of peat are received on boards fed over a roller table, the streams of peat being cut into suitable lengths and the boards of peat transported on small wagons from which they are taken and spread on the bog surface to dry. Another method adopted is to run the peat pulp into wagons and transport it to the drying ground, on which it is tipped and levelled to form a layer 5 or 6 inches thick. Various mechanical devices are employed for this purpose, one machine being like a snow plow, and others, such as the Jakobson press and Moore's spreader, laying down the peat into long strips with partings between. The peat layer is then cross-cut by means of a disc cutter. The excavation of the peat has usually been carried out by hand, the peat being thrown on to the bank, filled into wagons and taken to the macerator. The first attempt made to introduce labor aiding appliances was to fix a simple elevator to the hopper of the peat machine, the peat being dug and shoveled on to this. Even then large numbers had to be employed to dig the peat, and the next advance was to employ a dredger of the ladder type, which dredged the peat and delivere it into the hopper of the peat machine direct.

The system of removing separate blocks of peat on boards and spreading them to dry involves the employment of very considerable numbers and hence high costs of production. To get over this objection the Jakobson press and Moore's spreader were devised, the peat pulp being brought from the macerator to the Jakobson press in tip wagons on a narrow gauge railway, but in Canada a movable telpher system was adopted to convey the peat to the Moore spreader.

Even these systems involved a considerable amount of

labor, and within the last 5 years endeavors have been made to design a system which would be purely automatic. At least three of the principal firms manufacturing peat machines in Germany were engaged on the solution of this problem just before the war, and even in 1914 a certain measure of success had been achieved. It is difficult to obtain information of what has happened since 1914, but according to details published, tests carried out in 1915 showed that high outputs had been achieved, and sufficient raw peat to produce up to 75 tons of air-dried peat was excavated and spread by a single machine attended by 4 or 5 men during the course of a ten-hour day.

Thus with these automatic machines the output per worker per day will be sufficient raw peat spread to produce at least 15 tons of air-dried peat, whereas at Ticknevin a cutter, a catcher and a wheeler only spread sufficient to produce 3 tons of air-dried peat, or one ton per head per day. With the Dutch method the cutter alone does this work, and hence his output is 3 tons per day, and to do this it is worth remembering that he has to cut up, detach and pitch as separate blocks between 20 and 25 tons of raw peat, which represents no mean day's work.

The present tendency is to concentrate the excavating, macerating, and sod forming and spreading mechanism in one unit. This allows of greater concentration of power units and requires the minimum of supervision and labor.

The dredger excavates the peat from the bog, delivers it into the hopper of the macerator, which in turn forms it into separate pieces. These are automatically placed on a conveyor band which moves out from the macerator as it is gradually loaded, and when completely loaded it automatically tips its contents on to the bog. In this way a strip 100 yards long by 14 inches wide is covered at the same time with the formed peat blocks, and the whole machine then moves forward 14 inches and the next strip of peat is laid down as before. The conveyor-girder is supported on mono-rail trucks or on caterpillar tractors.

The peat when spread flat upon the bog is treated just as ordinary "hand cut" peat, and subjected to the usual turning, footing and stacking operations.

Some people are inclined to argue that "the man with the slane" will prove more efficient for winning peat than mechanical appliances, and base their arguments on some published figures of costs for mechanical winning. It may be true that in the past peat could on the small scale be won more cheaply by hand than with machinery because the proper methods had not been developed and cheap labor was available, but with the

recent improvements in mechanical excavating and handling apparatus there is no reason whatever for supposing that peat can be won more cheaply by hand than by mechanical appliances. The hand loom has been displaced by the power loom for manufacturing on the large scale, and in every other manufacturing operation the present tendency is to introduce labor-aiding appliances as far as possible.

The following figures giving the output of coal per head in the three principal coal-producing countries will emphasize the necessity of introducing some means of increasing the output of peat per person employed.

Output per person employed above and below ground in mines (1913):—

	Tons per annum.
Great Britain	259
Germany	273
U. S. A.	681
Peat winning by hand	130
Peat winning by mechanical means	230

It must be remembered that the season for peat winning is limited to 6 or 7 months, whereas the coal mining continues during the whole year. When we bear in mind that even with mechanical winning the 230 tons of peat is only the calorific equivalent to 115 tons of coal and that even in Great Britain the output per operative employed in the mines is 130 tons in six months, the necessity of raising the output of peat by the use of every mechanical device will be obvious.

The collection of peat can be considerably facilitated by mechanical appliances so that the labor required for handling, loading and unloading may be reduced to a minimum and production correspondingly increased. The season for peat winning is short and a little consideration of the numbers required to conduct operations on a large scale will lead to the conviction that it can only be done satisfactorily by the application of mechanical methods.

Uses of Peat.

Attempts have been made from time to time to make paper, building material, alcohol, petrol and clothes from peat, but the main uses of peat must continue to be for peat moss litter, peat dust for use in the manufacture of cattle feeding, and peat fuel for domestic and industrial purposes, including under the fuel the various distillation products.

There are a number of peat moss litter works in Ireland. In the south the principal ones are The Turraun Peat Co., Fer-

bane, in the King's County; The Rahan Peat Works near Tullamore, also in the King's County; and the Irish Peat Industry near Edenderry. In the north, the Irish Peat Development Co. have a large works at Maghery, County Armagh; and there is also the United Kingdom Moss Litter Co.'s Works at Portglenone, County Londonderry. These works have substantial iron buildings and have continued to increase their output in recent years. Both moss litter and peat dust are manufactured, the latter being used for packing fruit and for cattle feeding. Owing to the rapid introduction of motor-driven vehicles in the towns it cannot be said that the demand for moss litter is likely to increase, and in the country there is usually plenty of straw available. Therefore, if peat is to be used to an increased extent it must be for fuel for domestic purposes, or for the production of light oils by distillation. The use of peat as a domestic fuel is well understood in this country, and I shall confine my remarks to its use for power production.

The Utilization of Peat for the Production of Power.

We have now to consider in what way the peat, when won, may be utilized for the production of power. A great deal has been written on this subject and very definite opinions expressed by many as to the best and most efficient way in which the heat energy stored in the peat may be converted into electrical energy. Apparently we seem bound to regard the production of electrical energy as the end to be aimed at whether that energy is to be derived from peat, coal, or water power. This is no doubt due to the flexibility in use possessed by electrical power and the ease with which it can be transmitted over long distances from large stations where the production units are concentrated.

There are two main lines of procedure open to us. The first is to burn the peat with its fixed carbon and volatiles to complete oxidation in a water tube or other form of steam boiler and then use the steam thus produced in a turbo-generator for the production of electrical energy. The second alternative is to consume the peat in a gas producer, the peat being partly oxidized with the production from each ton of peat used of some 60,000 to 80,000 cubic feet of a power gas of low calorific value (say 100 to 150 B.T.U. per cubic foot), the power gas produced being used in a gas engine or in a gas-fired steam boiler and the steam used in a turbo-generator.

It may be as well to indicate briefly the action which takes place in the gas producer. There are many types of producers, and time will not permit of an examination of these. In the

simplest form it consists of a vertical cylindrical shaft or furnace into which the fuel is fed at the top through a gas-tight door, and as the fuel at the bottom is consumed it sinks lower into the producer, the temperature rising as it sinks. In the upper portion of the producer, any water contained in the fuel is driven off, then the volatiles are liberated, and lower down the carbon is burned to CO_2. The CO_2 is decomposed in the next zone and CO formed with the incandescent carbon. The steam passing through the incandescent bed is split up with the formation of CO and H_2, and about 2 to 4 per cent. of hydrocarbons are also formed. The CO, H_2, hydrocarbons, volatiles and atmospheric N_2 then leave the producer at the top. The steam is used so as to lower the temperature and increase the thermal efficiency of the producer, as well as to form "water gas," CO and H_2, and to allow a greater efficiency in the recovery of ammonia. The type of the producer varies somewhat with the fuel used, whether it be wood waste, anthracite or bituminous coal, lignite or peat, but the principles governing the reactions are the same.

Allowable Percentage of Moisture in Peat for Producer Work.

Several leading manufacturers of gas producer plants have claimed that they have been successful in using peat containing 60 per cent. to 70 per cent. of moisture, whereas to burn peat in the furnace of a steam boiler the moisture content ought not to exceed 30 per cent. to 35 per cent. Since steam has to be supplied to the producer when using a dry fuel, it would naturally be a great advantage if the moisture required could be supplied by the peat, thereby avoiding the necessity of drying the peat to so great an extent. If it were permissible to use peat with 60 per cent. to 70 per cent. of moisture it would render the industry less dependent on the vagaries of the weather, considerably extend the peat-winning season and simplify the whole problem of preparing peat fuel. The possibility, however, of using peat with as high a moisture content as 60 per cent. in a gas producer is doubtful, but even if possible it might not be economic to do so, and in practice we find that in the Italian installations at Orentano and Codigoro the peat is dried by exhaust gases so that the moisture content is reduced as nearly as possible to 33 per cent. Haanel, in the publication of the Canadian Department of Mines, is strongly of the opinion that the best results are obtained with 33 per cent. moisture peat. As to the possibility of using 60 per cent. moisture peat he says (Peat Lignite and Coal, p. 34): "Under the most ideal conditions, the quantity of heat generated by the burning of peat containing 60 per cent. mois-

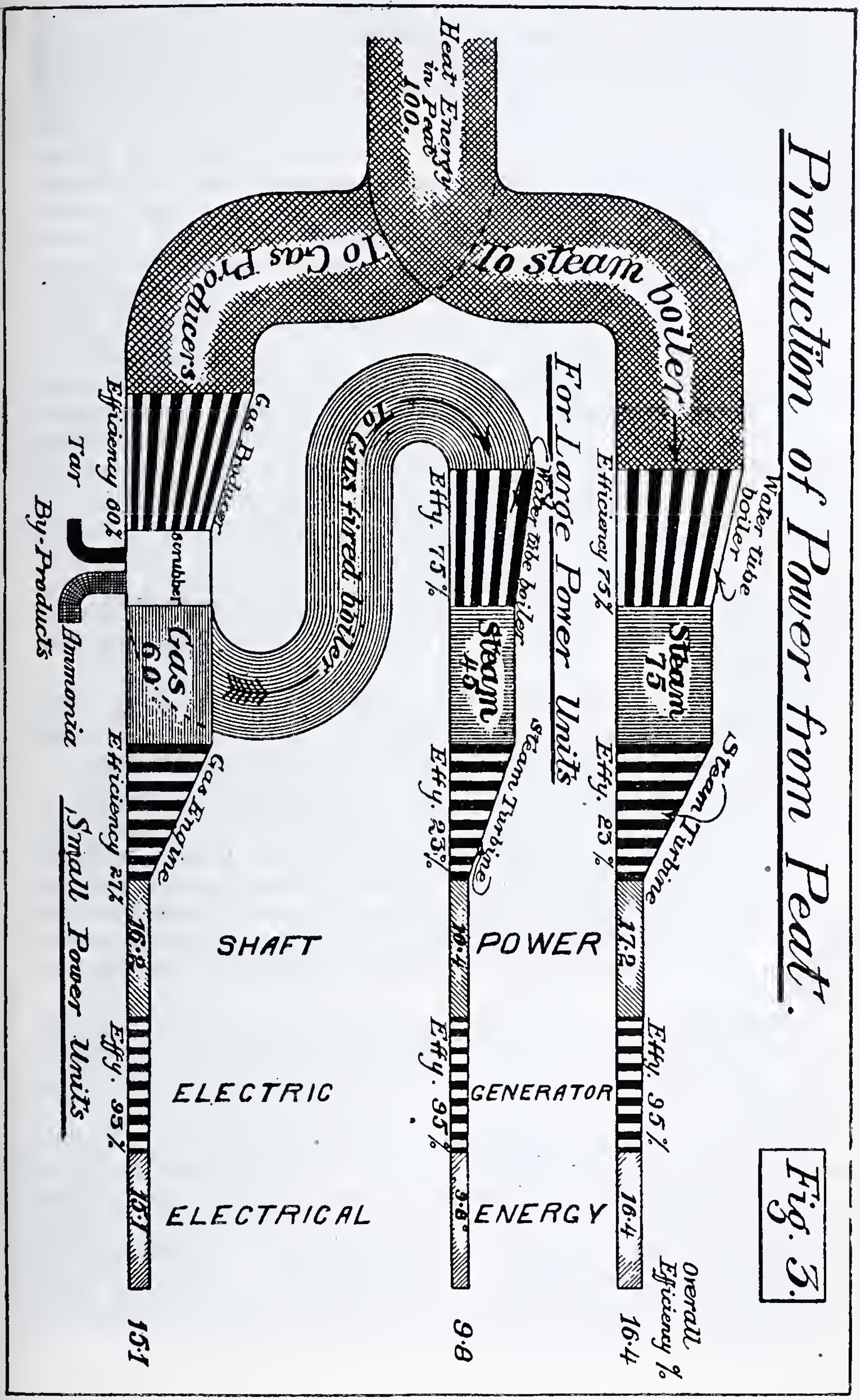
ture in a producer is not sufficient to effect the various reactions and provide for the losses. It is, therefore, impossible to produce from peat containing so high a moisture content a power gas of the heating value claimed. It is more within the realm of probability that complete combustion would have to take place in order to permit the production of the necessary quantity of heat—in which case the gas resulting would contain no combustible components whatever except perhaps a small percentage of hydrogen."

It is possible that in many cases the peat is really not so wet as stated, and that the 60 per cent. moisture only relates to the surface layer of the peat. I know of one case where peat containing 60 per cent. to 70 per cent. moisture was said to have been used, but closer inquiry elicited the fact that the percentage of moisture was not determined analytically, but that the peat "felt" as if it contained 60 per cent. to 70 per cent. water. There is no doubt that peat with 40 per cent. to 45 per cent. moisture may be used in a specially constructed producer, and this is a very great advantage which the gas producer can claim over the steam boiler.

The diagram (Fig. 3) is intended to indicate the possible ways of utilizing the energy in the peat fuel, and I do not wish to express any personal opinion as to which method will be found ultimately to be more economical. It is probable that each system will have its own sphere within which it will be the best to adopt. The diagram has been prepared to represent these operations, and to do this, certain efficiencies have been assumed for each stage at which one form of energy is converted into another. Most of these factors are subject to considerable variation, and fairly high efficiencies have been assumed for each stage.

Following the upper line in the diagram, about 75 per cent. of the 100 heat units in the peat are available for the production of steam by burning the peat in a water-tube boiler, and these 75 steam units when used in a modern steam turbine, with a thermal efficiency of 23 per cent., will give 17.25 units of shaft power which in turn yield 16.4 units as electrical energy. Taking the lower line the 100 units put through a gas producer with 60 per cent. to 70 per cent. thermal efficiency will give, let us say, 60 units of energy contained in the gas if by-products are recovered. At the same time, certain by-products in the form of tar and ammonia are produced and these may be recovered, the latter as sulphate of ammonia for which there is wide demand.

There are two alternative methods open to us for the utilization of the gas. It may be sent by the middle route and



Production of Power from Peat.

Fig. 3.

burned in a gas-fired boiler, the resulting steam being used in a turbo-generator. A thermal efficiency of 75 per cent. to 80 per cent. with the gas-fired boilers is said to be attainable, but it will be seen that we have one extra step introduced so that two operations are necessary to convert the heat energy in the peat into steam as compared to one in the peat-fired steam boiler. This involves further loss of energy, and in addition, increased capital charges must be borne, so that unless the profits on the by-product recovery plant are of sufficient value this system cannot compete with the direct peat-fired steam boiler. The energy produced by this system $= 100 \times .6 \times .75 \times .23 \times .95 = 9.8$ per cent. of that put in. The method, however, allows large units to be employed while at the same time by-products are recovered. The second alternative is to use the power gas from the producer in a gas engine which in turn works a generator. This method offers fairly high efficiencies, but it is doubtful if it can be employed on the large scale as it is said that serious mechanical difficulties are experienced in the working of large gas engines of 500 h.p. and upwards, and 300 h.p. would appear to be a useful limit. For such powers as 300 h.p. this method gives good results. About 16 per cent. of the heat energy put in appear as shaft power, and ($100 \times .6 \times .27 \times .93 = 15.1$) about 15.1 per cent. as electrical energy.

Little can be said about the gas turbine which would form another alternative. So far it has not proved successful and does not appear to have got beyond the experimental stage.

It must be remembered that considerable quantities of heat and power are required for the recovery of by-products and that this will very considerably reduce the power available for distribution. The producer if run for the production of the maximum amount of ammonia will have a much lower thermal efficiency than that stated, and only a very careful survey of all the factors concerned can show which method is the best to adopt.

From the peat tar many useful products may be derived, and Professor Morgan, F.R.S., and Mr. Scharff have produced some very effective antiseptics and disinfectants by fractional distillation.

Experts hold conflicting opinions on the question of the best way of utilizing the energy contained in the peat, and this is not to be wondered at when the same question in the case of coal is regarded as an open one by those best able to judge. So much is this the case that an elaborate series of experiments is about to be undertaken by the Fuel Research Board in their Fuel Research Station at East Greenwich, where a special sta-

tion costing well over £100,000 has been erected. Work on the carbonization of coal at low temperatures will be carried out, and among other questions to which it is hoped to supply answers are the following:—

> "Can electric power be obtained more cheaply if the coal used for steam raising is first subjected to processes of carbonization and gasification?"
>
> "Will the more scientific development of the preparation and use of fuel enable the peat deposits of the United Kingdom to take a serious place as economic sources of fuel for industrial purposes?"

The use and value of coke for the direct firing of steam boilers, and its gasification in producers for the manufacture of low-grade fuel gas and the recovery of its nitrogen as ammonia, will also be tested. Before leaving this important matter, I think it as well to quote a passage from the Report of the Fuel Research Board where they allude to the proposals to set up large super-power stations:

> "In this connection it has been suggested that the cost of producing power from coal in this country would be substantially reduced if, instead of burning the coal directly under the steam boilers, it were first subjected to carbonization and gasification processes which, in addition to fuel gas, would yield valuable by-products. Plausible statements have been issued showing the enormous savings or profits which would accrue if schemes of this sort were adopted. Unfortunately these estimates have generally been made on a very slender foundation of knowledge and experience. On the other hand, those who by experience and practice are best qualified to judge, hesitate to prophesy as to what the economic result of a combined carbonization and power generating scheme would be, but they agree that the interests at stake are so great that the question ought to be authoritatively answered once for all."

To arrive at a sound conclusion as to the best method to adopt for the utilization of the peat we must take into account not alone the overall efficiency of the processes involved, but also the labor, depreciation, maintenance and capital charges. We must further take account of the profits from the by-products obtained when peat is gasified in a producer, and this involves the estimation of the costs of production of the by-products with the labor, maintenance, capital and amortization charges on the recovery plant. Even then we are dealing with sulphate of ammonia, a product the price of which

has been subject to considerable variation and one for which, owing to recent developments in connection with the war, it would not be easy to predict a price a couple of years ahead. We must further remember that the process of gasification in a producer can be varied within wide limits and the working of the system and its thermal efficiency depends on the end in view whether it be the maximum production of by-products or the maximum production of power gas. Both these objects cannot be achieved at the same time, and, in a measure, the failure to recognize this point has led to a good deal of confused thought and rather optimistic forecasts as to the possibilities of by-product recovery plants. The yield of sulphate of ammonia is dependent on the percentage of nitrogen in the peat, and therefore, whereas by-product recovery on one bog might pay, it would prove a failure on another. It will therefore be seen that the problem is a very complex one.

Portadown, Co. Armagh.—I now propose to describe a few of the better knewn peat power installations. There are only two installations in Ireland worthy of notice where peat is used for the generation of power. In the west at Clifden, in Galway, the Marconi Company use some five or six thousand tons of air-dried peat per annum in locomotive boilers to generate the power required in connection with their wireless station. It is probable, however, that the producer gas plant at Mr. Hamilton Robb's linen factory at Portadown is the more interesting. Here two Crossley producers, each of which is said to be capable of developing 200 B.H.P., are used to supply three Stockport gas engines, two rated at 120 B.H.P. and one at 150 B.H.P. As a rule, about 250 B.H.P. is developed, and under test the consumption has at different periods been stated to amount to from 2.5 to 3.16 pounds of 25 per cent. moisture peat per B.H.P. hour. Adopting the latter and more recent figure which is equivalent to 4.24 pounds per kw. hour, this, at 10s. per ton for the peat, would work out at .22 pence per kw. hour, or about £8 per kw. year for the cost of the fuel alone. From published details the plant appear to show a considerable saving on the cost when coal is used. About 600 people are employed, and 1,000 tons of peat are used in the producers, no attempt being made to recover by-products, owing to the small scale of the plant. In addition, 2,500 tons are used in boilers to produce the steam required for heating and humidity.

In Great Britain, with the exception of the plant of the Wetcarbonizing Co., at Durfries, run by the War Department for the production of carbonized peat briquettes for use in the trenches in France, all the peat is won by hand. At Dumfries

the peat is dredged from a barge and pumped to the Wetcarbonizing factory. A considerable quantity of peat fuel is cut for domestic purposes in Somerset, Devonshire, Cambridge, Lancashire and Yorkshire, but with the exception of the production of peat moss litter and peat dust I do not know of any industrial use of peat in Great Britain. Many attempts have been made and considerable sums of money spent in Great Britain in trying to develop various processes for the dehydration and distillation of peat, but with no greater measure of success than in Ireland. For instance, about 40 years ago a peat charcoal factory was established on Dartmoor and a standard gauge railway line 4½ miles long built to connect the Sheepstor factory to Bridestowe Station on the L. & S. W. Railway. The peat here is well humified and somewhat resembles our mountain peat. The charcoal produced was sent to Plymouth, where it was used for metallurgical purposes, or exported to France, but the works closed down after a little while. Then came a succession of people, some trying distillation processes, others pressing the peat or trying the action of centrifugal apparatus, and lastly during the war, distillation was again tried with, it is said, some success. I understand that the Duchy of Cornwall contemplate distillation operations on a large scale at Sheepstor, Dartmoor. At least £100,000 has been spent at Bridestowe by the various syndicates concerned. To the south of Sheepstor, 70 years ago, a large naphtha works was erected at Princeton, Dartmoor, on the site of the present prison, and large quantities of peat were used while the works remained open.

In United States, owing to the abundant coal supplies available, comparatively little development of peat has taken place, but none the less the peat deposits have been surveyed and their possibilities investigated.

Canada.—A number of attempts have been made in Canada, chiefly in Ontario, to win peat mechanically and some work on carbonizing has also been attempted. Very complete surveys of the peat deposits have been carried out by the Department of Mines Branch and valuable experimental work done on the use of peat in Körting producers and in water-tube and locomotive boilers. They have shown that in the producer without by-product recovery, a thermal efficiency of 66.8 per cent. is attainable and for the 60 H.P. gas engine and producer, from fuel to shaft, the overall efficiency was 26.3 per cent. With a water tube boiler the efficiency did not appear to exceed 62.5 per cent., which is low compared with the 74 per cent. reported from Weismoor.

On the peat bog at Alfred, Ontario, procured by the Cana-

dian Government for experimental purposes good work has been done on the solution of problems connected with mechanical winning.

Sweden.—Much work on the Ekenberg wet carbonizing system has been done and a further attempt by Mr. de Laval has been made on somewhat similar lines. In the former system the peat is pumped through a pipe and raised under high pressure to a temperature of about 200° C. by a steam jacket. The raw peat flows out through a pipe which is jacketed with the incoming cool peat and the process is thus made regenerative to a certain extent. The raw peat thus heated under pressure changes its gelatinous character, becomes black and parts with the greater portion of its water under pressure so that the water content is reduced to 50 per cent. Judging by results, commercial success does not yet appear to have been achieved. The de Laval process consists in causing the raw peat with about 95 per cent. water to pass at a high velocity through a spiral which is heated on the outer side. It is claimed that the peat substance is partially separated from the water so that it is raised to a higher temperature than the water. The high temperature causes an alteration in the structure of the peat and it may then be pressed to a low moisture content. If it were possible to produce any sensible separation of peat and water by centrifugal action it would obviously be applied direct to the dehydrating of peat. This has been attempted over and over again but without success.

Much work has also been done in Sweden on the production of peat powder. The peat is first air-dried to 40 per cent. moisture and then ground to a fine dust and dried artificially to about 2 per cent. to 15 per cent. moisture. It has been used successfully on locomotives, the stoking being automatic, and on a test run of 62 miles with trainloads of over 750 tons a speed of 30 m.h.p. was kept up, the consumption being less than 1½ pound of peat powder compared with one pound of British coal.

Germany.—In Germany considerable attention has been given to the use of peat for the production of power. In the large Central Power Station at Wiesmoor Friesland plant capable of producing 5,000 h.p. has been provided. The peat is burned in a boiler furnace with a step grate and a thermal efficiency of 74 per cent. is said to have been secured. The steam from the boilers is used in turbo-generators and on some occasions the consumption of peat was as low as 5¼ pounds per kw. hour. The current is transmitted to Emden and Wilhelmshaven where it is used in the naval yards and to run tramways in the neighborhood. The transmission lines follow

the Ems-Jade canal and the current is used for the operation of the canal. About 30,000 tons of peat are used per annum, and while some of it is cut by hand the greater portion is machine peat, about 35 peat machines being employed previous to 1914. Many of these were Dolberg machines with elevators and macerators and at least two Otto-Strenge and one Dolberg with mechanical excavators were used, and there is reason to believe that some automatic machines of the Wieland type were also employed.

This ambitious scheme of peat development in Friesland is generally regarded as having a political significance and was meant to encourage colonization, thus keeping greater numbers at home in Germany while at the same time providing an electrical supply to Emden and Wilhelmshaven, so that should the coal supply be interrupted during a time of war, an alternative supply would be available. The station is worked by the Siemens-Schuckert Co., and, according to a report of March, 1915, the plant has increased to eight water-tube steam boilers with 9,000 r.p. in turbines and three-phase generators.

Russia.—It was estimated some years ago that five million tons of peat was won mechanically each year in Russia and that the number of peat machines so used was well over one thousand. In 1900 the Government gave large subsidies to promote researches in peat and also decreed reduced freight rates for peat on railways. The Bogerodzk power station, which is linked up with Moscow, 43 miles away, is the largest in the world run on peat. It began work late in 1914 with a capital of £660,000, the plant having a capacity of 10,000 kw. There are three Zoelly turbo generators of 5,000 kw. each, and two excavators and 25 hand-fed peat machines are employed to produce the necessary peat fuel. A large amount of the power is supplied to weaving factories in the neighborhood and the surplus power is transmitted to Moscow, and in this way a high load factor is obtained. The peat is burned under water-tube boilers, but the published details of the peat consumption do not appear to be reliable.

Reclamation and Cultivation of Bogs.

The time at my disposal will not permit of more than a few passing remarks on the possibility of cultivating our bogs to a greater degree than at present.

The Bogs Commissioners of 1809-1814 in their reports expressed their confidence in the possibility of draining and reclaiming the bogs and converting them into valuable agricultural land. Their estimates, most carefully prepared and

based on actual experience, showed that when all contingencies had been allowed for, a handsome return would remain on the capital invested in such work. Before peat land will grow anything, lime must be added to neutralize the peaty acids and certain other fertilizers must be applied if results are to be obtained. The lime required is to be had in abundance, as most of the bogs in the central plain lie on marl, which is almost pure calcium carbonate, and limestone gravel and limestone are to be had near to the bogs.

Had the reclamations suggested been carried out at that time there is no doubt that they would have proved successful, but this is not the time or place to enter into the events, domestic and international, which prevented the scheme proposed by the Bogs Commissioners from being carried out.

Today the estimates of their engineers would have to be seriously recast, as the standard rate of wages in those days in County Galway was 1s. to 1s. 1d. a day. On the other hand, it would appear from some recent accounts received from Germany that the labor involved in the cost of reclamation has been considerably reduced by the introduction of new methods.

It will be said that there are many thousands of acres of land in Ireland which are more suitable for reclamation than bog land and which should come under cultivation first. I am not in a position to dispute the facts, but you cannot expect 100 per cent. efficiency in these matters, and there will be always some land which might be better cultivated.

In Ireland one-seventh of the area of the country is under bogs, and if we allow for the portion already reclaimed there must be an area of one-tenth of the country which consists of unreclaimed bog land. If only one-third of this were cultivated it would constitute a substantial addition to the area under cultivation in the country. The solution of the problem no doubt depends largely on the carrying out of a proper system of arterial drainage, the beneficent effects of which would confer inestimable advantages in other directions.

I had the advantage this last summer of paying visits to several of the principal peat areas in England, and I am sure many of those present know to what an extent this peat land is utilized for agriculture. Near Princetown on Dartmoor, although the rainfall is 80 inches per annum and almost the highest in the country, we find that the Prince of Wales through the Duchy of Lancaster was last year reclaiming some 300 acres of peat moorland which until recently had been let at 2s. per acre. It was a revelation to see this rough moorland brought under the plow with its disused turf banks and

boulder-strewn surface. It is the intention to reclaim up to 400 acres of this land, and the scheme is being supervised by a Belgian expert.

In Cambridgeshire and Lincolnshire many thousands of acres of "fen" land have been reclaimed by simple methods and form some of the best potato land in the country. From time to time this reclaimed land is sold and fetches £50 to £80 per acre. It must be borne in mind that all this "fen" land is liable to flooding, and is only kept drained by pumping, for which a drainage rate of 5s. per acres is levied. The profit from this potato land is as much as £15 to £20 per acre per annum.

Going north into Lancashire one sees many thousands of acres of moss land on Rawcliffe and Pelling Mosses, between Garstang and Fleetwood, which have all been thoroughly drained and reclaimed. On either side of the road you see excellent crops of oats, potatoes and wheat growing on both the uncut and cutaway bog. Late in July I saw a splendid crop of wheat grown on the uncut bog, and this year's peat fuel supply cut from within 12 inches of the wheat crop. I need only mention Chat Moss, 2,500 acres of which were purchased by the Manchester Corporation from the de Trafford Estate, and all of which has now been reclaimed and is under cultivation with the exception of 130 acres.

I do not wish to trouble you with too many facts, but I think I am justified in saying that a clear case for more extended development of the peat deposits exist from an agricultural standpoint. Had I any doubts on this point they vanished during my visit to the English peat deposits last year. Perhaps it will be urged that the nature of the English deposits is different from ours, and that nature has endowed English peat with more valuable properties for agriculture. If so, surely another injustice has been added to the lengthy list. The simple fact that it pays to cultivate peat land in England makes one ask, "if so, why not here?"

Conclusion.

I wish to express my great indebtedness to Mr. E. J. Duffy, B.Sc., B.E., for his help in preparing the diagrams used to illustrate this lecture and for many useful suggestions. I have avoided, so far as possible, actual reference to estimated figures of cost both for peat winning and for by-products, as, at the moment, we have no definite basis on which to fix the cost of labor or the cost of materials or the output.

The country feels that it ought to know from an impartial

source what are its resources in peat, coal and water power. We have the peat fiends and the coal and water fiends each vieing with the other in the extravagance of their statements, mostly founded on imperfect knowledge of these subjects. What the country wants is the truth and the whole truth about its industrial resources—that is the first step previous to development. I think it is in a fair way now to get this information in reference to its main sources of power. When that information is forthcoming, it should show what is possible and what is not, so that only such schemes will be undertaken as will be to the ultimate advantage of the country.

CANADIAN PEAT FOR FUEL.*

By A. A. Cole.**

Canada has large coal resources both in the east and west, but Central Canada (the province of Ontario in particular) is dependent to a very large extent on the American coal fields. Owing to labor troubles, transportation difficulties and general war activities, the fuel situation in Central Canada for the past two or three years has become increasingly difficult, and at times very acute. This led the Ontario Government to make an appropriation in the session of 1918 to ascertain what could be done with wood and peat, to partially offset the shortage of coal. It was almost decided to build an Anrep plant and test it on an Ontario bog, when it was found that the Federal Government was planning to build a peat plant from the design of Mr. E. V. Moore of Montreal.

The Federal and Provincial Ministers of Mines, therefore, decided to build both machines for the experiments, the cost of the investigation to be divided equally between the two governments. The problem was to show whether peat fuel could be produced and marketed commercially in competition with coal.

The investigation was placed in the hands of a committee of four: R. A. Ross, Montreal, and B. F. Haanel, Mines Branch, Ottawa, representing the Federal Government, and R. C. Harris, Toronto, and A. A. Cole, Coblat, representing the Ontario Legislature. E. V. Moore, of Montreal, was appointed Engineer to the committee.

*Presented at the Annual Meeting of the Canadian Mining Institute, Toronto. March, 1920.

**Mining Engineer, T. & N. O. Ry., Cobalt,, Ontario. Member of the Canadian Peat Committee.

General Principles of Preparing Peat Fuel for Market by Sun-Drying Process.

The method of preparing the peat fuel that is adopted by the Peat Committee is known as the wet process, the product being termed "air-dried machine peat." This process is the only known economical one for the manufacture of peat fuel and is employed in Europe for the manufacture of millions of tons of peat annually.

The process consists essentially of excavation, maceration and spreading, allowing the sun and air to do the drying and curing. The peat when taken from the bog contains about 88 per cent. moisture, and none of this water is removed mechanically; in fact, if the moisture content is below this amount it may be advantageous to add water to make the material work up to the best advantage.

The amount of maceration given to the peat determines to a marked degree the quality of the fuel produced; maceration increases the density of the finished product and hence also increases its value.

The peat is spread on the surface of the ground for drying, usually on a part of the bog which has been cleared and drained. The drying and curing takes from two to four weeks to complete. Towards the end of this time the peat is turned once and a few days later is coned or stacked in hollow piles.

When the moisture has been reduced to about 95 per cent., leaving a fuel with a moisture content of 25 per cent., the peat is ready for marketing.

General Description of Two Machines to Be Tested.

The Peat Committee has constructed two peat machines of different types and with them will ascertain the commercial feasibility of manufacturing peat fuel in this country. Expensive manual labor makes it more imperative that mechanical appliances should be employed as extensively as possible.

Plant No. 1 is known as the Anrep Plant. In its design care was exercised to adhere as closely as possible to the original drawings, which were made by the inventor, the late Aleph Anrep, Sr., for the equipment used in distributing the peat. The excavator, however, was re-designed in the light of experience gained with it in 1914. The machine was placed on caterpillars, and a new design of bucket-dipping element installed.

Excavation is made along the side of a ditch, the slope of which is about 45°, and the depth of the cut about 9 feet.

The excavated material is passed through an Anrep macerator, after which it is ready for spreading. From the macerator it is discharged into open cars which are run out onto the spreading field by means of an endless cable haulage system. When the car reaches the spreader, which is operated as a separate unit, it is stopped and discharged, then is re-engaged to the cable system and continues around the field to its starting point.

The spreader smooths out the wet peat into a layer about five inches thick and cuts it into long, narrow rows by means of revolving discs attached to the rear of the spreader. The spreader lays down a row at right angles to the ditch being excavated.

The endless cable haulage system is laid out on the field in the form of a square and the peat is laid out alongside the cableway, each row being the length of one side of the square. As soon as a row is completed the tracks are moved over, the spreader reversed and a new row started.

Plant No. 2, the Moore plant, is identical in principle with the Anrep plant as regards excavation and maceration, but differs essentially in the method of spreading.

In this plant, the peat, on leaving the macerator, is delivered to an endless conveyor belt carried by a fabricated steel arm 160 feet in length which extends from the plant platform proper of the opposite side from the excavator and runs at right angles to the line of the ditch. The wet peat runs out on this belt conveyor until it reaches a deflector which turns it into the spreader. The plant itself is carried on two caterpillars and the belt conveyor arm on a third placed 100 feet from the platform proper. The spreader is attached to the belt-conveyor arm and is operated by a chain belt drive which runs through the conveyor arm, operating also the third caterpillar. In setting out one row of peat the plant travels the full length of the ditch, and as soon as the row is completed, the spreader is moved in its own width along the conveyor arm and attached on the opposite side, so that another row parallel to the first and adjacent to it is laid out as the machine returns along its working face. These operations are repeated until the field is covered. The spreading field is therefore somewhat over 160 feet in width and is the same length as the ditch. To work to the best advantage, it is necessary that the ditch should be of sufficient length so that when the field is completely covered, the first row spread will be ready for harvesting. Much of this first row will have been used in operating the plant so that the rest can easily be removed and the spreading of the first repeated. While

this is being done the remainder of the belt conveyor can be used to convey the peat from Row No. 2 to the permanent track at the end of the conveyor, where it is delivered into small open cars and run in trains to the shipping platform. Mr. Moore's idea in this method of manufacturing peat is to make the handling of this material as far as possible mechanical, and in this he has succeeded to a marked degree. Thus the labor to run the No. 1 plant is from 13 to 15 men, while No. 2 plant requires from 5 to 7. The obvious disadvantage of the No. 2 plant is that it requires a very long ditch to keep it operating continuously, but this, on the other hand, will be overcome as the length of the arm is increased.

The capacity of each plant is about six tons per hour, and the best results are obtained by working two shifts per day.

Work Accomplished and Work Yet to Be Done.

The Alfred bog was chosen as suitable for the installation of the two peat machines for the demonstration of the practicability of manufacturing peat fuel commercially in Canada, as it already has one working face prepared and a drying field which was partially drained. This bog is situated on the main line of the C. P. R. between Ottawa and Montreal.

The analysis of the peat content of the portion of the bog being worked is:

	Per cent.
Volatile matter	69
Fixed Carbon	24
Ash	7

Heating Value, 9300-9500 B.T.U. per lb., (absolutely dry peat).

The season at Alfred, which is similar to that of the greater part of Southern Ontario, consists of from 100 to 120 days.

The price, in carload lots, at which the peat is being sold f. o. b. cars at Alfred station, is $3.50 per ton. This allows for a reasonable profit over and above the cost of production, and includes a 10 per cent. depreciation and a 10 per cent. amortization allowance.

A ready market is obtainable in Ottawa and Montreal for the product from many such machines as those built for the Peat Committee.

It is not expected that peat fuel will entirely replace coal,

even where peat is most plentiful, but for certain special uses it has advantages over coal, and if used for these purposes will materially help to overcome the fuel shortage.

Peat can be used to advantage in open grates and in cooking ranges, but is not recommended for use in furnaces except in the autumn and spring when light fires are needed or in conjunction with coal when a coal fire has to be hurried.

The program planned for the coming season is to work both plants to capacity and market the product, showing thereby what can be done on a commercial basis. It is also proposed to test a small three-man machine which is now being built. It is hoped that such a machine will be suitable for a great many small bogs of comparatively shallow depth throughout Ontario and Quebec that are too small to be worked with the larger machines.

(Reprinted from Monthly Bulletin, The Canadian Mining Institute.)

BOOK REVIEWS.

Agricultural Value and Reclamation of Minnesota Peat Soils.

By F. J. Alway,
Division of Soils.

Published as Bulletin 188, of Minnesota Agricultural Experiment Station, March, 1920.

Peat soils occupy about one-eighth of the surface of Minnesota, or approximately 7,000,000 acres, according to the most recent estimate. Most of this is in the northern counties, but extensive tracts are found in some counties in the southern half of the state..

Tamarack and spruce occupy most of this land. On considerable areas the trees are of fair size, but in general they are too dwarfed to furnish merchantable timber. A small part of the peat lands form natural meadows on which is cut wild hay, or wire grass for carpet making. The hay is low in yield and very inferior in feeding value compared with that from clover and tame grasses. Only a few thousand acres have been brought under the plow and from most of it the returns have been very disappointing, although on occasional fields excellent crops have been raised.

Future Possibilities.

The future possibilities of these lands lie in their use for agriculture, forestry, and industrial purposes. European experience has shown peat lands to be eminently adapted for tame meadows and pastures, but unpromising for forestry purposes. They also have been shown to be able to produce good crows of vegetables, forage crops, and grains, insofar as the climate permits. The use of the bog for agriculture would tend to hasten rather than retard their development for any industrial purposes for which the peat in them may be suitable.

Sources of Information.

As sources of information regarding the crops adapted to these soils, the methods of drainage, fertilization, and management necessary for their profitable farming, and the difficulties to be encountered in their reclamation, we should give first consideration to the results obtained at the European experiment stations, especially to those of Germany and Sweden,

where systematic field experiments have been carried out for thirty years or more. In Minnesota no provision was made for such work until very recently, while the field experiments reported from other states in this country have been of a very limited character. On the whole, the results obtained in the United States are in accord with those reported from Europe, where peat land cultivation had developed slowly during several centuries, in the course of which the various simpler methods of reclamation were thoroughly tried out and generally with disappointing results. The peat soils differ so much from ordinary or mineral soils that a satisfactory solution of the problem of their reclamation had to await the development of agricultural science and the establishment of peat experiment stations.

Methods of Farming.

Methods of farming on ordinary soils are in part not suitable on peat. The latter, in general, are characterized, even when first brought under cultivation, by a marked deficiency of certain plant nutrients, with the result that their reclamation is largely dependent upon the use of suitable commercial applications—potash or phosphate, or both together, and in some cases of nitrogen and lime only. They vary so widely among themselves in the chemical treatment required to make them productive that, while all peat soils may be considered as potentially agricultural, for some of them the cost of the necessary applications would make their reclamation at the present time unprofitable except for truck or other specialized farming. The mistaken belief that all peat soils would respond to the same treatment has led to many of the disappointments in their cultivation.

Chemical Requirements of High-Lime and Low-Lime Peats.

According to their chemical requirements peat soils may be divided into two groups—high-lime and low-lime peats. On the former liming is of no advantage, and from their practically inexhausted supply the nitrogen becomes available rapidly enough to render unnecessary the use of any form of nitrogen fertilizer for farm and garden crops. On the contrary, in the reclamation of low-lime peats liming forms an indispensable first step, while the nitrogen is so slightly available that a nitrogen fertilizer must be applied for grain, vegetable and forage crops other than legumes.

On the low-lime peats potash and phosphate fertilizer also are necessary. The high-lime peats, on the basis of their need of these when first brought under cultivation, may be divided

into four classes: (1) Those needing nothing, (2) those needing only phosphate, (3) those needing only potash, (4) those needing both phosphate and potash. On Minnesota bogs, those needing phosphate only have been most frequently encountered; elsewhere in the United States those needing potash only; but on Europe bogs both phosphate and potash are usually needed.

Within a few years after they have been reclaimed, most high-lime bogs on which the peat layer is not very shallow may be expected to show a need of both potash and phosphate unless they are used only as pastures.

Stable manure, which furnishes nitrogen as well as phosphate and potash, is valuable on peats, but usually it can be more profitably employed on mineral soils, if the farmer has these, except for occasional light applications to provide the bacteria of decay.

Using reclaimed land as pasture will greatly lessen the need of commercial fertilizers. Further economies may at times be effected by the application of mineral soil or straw and by the use of peat for litter.

Before spending much money on the improvement of a tract of peat land, it is wise to ascertain its initial chemical requirements by means of a systematic and laboratory investigation.

Drainage and Water-Level Control.

Drainage is the first essential step in the reclamation of these soils and peat land owners are likely to underestimate the need of laterals, the distance apart of which should be determined by the character of the substratum and of the peat as well as by the crops to be grown and the amount of rainfall. On the other hand, over-drainage should be guarded against, as in dry seasons the crops will suffer from drouth. Meadows need the highest water level and grains and cultivated crops the lowest, while pastures occupy an intermediate position.

One of the most important advantages possessed by peat soils is the abundance of moisture for crops throughout the growing season that may commonly be obtained by a system of water-level control. With this good yields may be had in seasons so dry that on adiacent mineral soils crops are light; for this reason the best yields on peat soils are often obtained when crop prices are highest.

Heavy Rolling.

One of the most important cultural operations on peat soils is the frequent use of very heavy rollers. Tractors exert a similar compacting effect.

Summer Frosts.

Peat soils are especially liable to summer frosts which on many bogs will greatly restrict the number of crops that may be successfully grown. A coating of sand or clay will greatly lessen the danger of frost.

Cost of Preparing for Crop.

The combined cost of clearing, plowing, and preparing the seed-bed varies greatly, being low for grass-covered bogs without roots or logs in their surface, but so high in the case of some of the most root and log infested bogs as to be prohibitive for ordinary farming purposes. On the latter it may be found feasible to secure pastures of clover and tame grasses without incurring the expense of plowing or removing the woody fragments.

Burning.

Burning the surface layer is in some cases desirable and at times is very profitable, but it should be practiced only after a careful consideration of the local conditions. Burning may ruin the drainage system, produce an alkali soil, leave a boulder field, or in the case of shallow peats, leave too little organic matter. In the first season after burning the crop results are usually excellent, but unless the peat layer is shallow and underlaid by a good mineral soil the beneficial effect will rapidly become less and may even entirely disappear at the end of the first season. In burning, extreme precautions should be taken to prevent the escape of fire.

Where an accidental burning has rendered clearing operations easy the land should be cleared and put into some crop before wild vegetation has occupied the surface. A clover-grass mixture is one of the most suitable crops for this purpose.

Where the peat layer has been removed by fire, the underlying soil, if a loam or clay. may be farmed by the ordinary methods used on mineral soils.

Method of Procedure Advised.

Extensive ditching projects for in advance of reclamation, which have been common in northern Minnesota, are to be attributed to the prevailing erroneous belief that drainage alone will make the peat lands productive.

When immediate reclamation is not purposed the grass-covered bogs had better be left to serve as wire-grass meadows, or drained just enough to allow the cutting of wild hay, while

the bogs with merchantable timber should be kept under proper forest management and all others left undisturbed until the would-be developers have satisfied themselves by systematic investigations and small-scale trials that reclamation will prove profitable.

Profit of Present Reclamation.

It appears that at present in the case of the greater portion of our immense peat acreage, the profit of reclamation is to be regarded as extremely doubtful, even under the most skilled supervision and with every resource and facility for conducting the work economically, while many extensive tracts could be improved only at a loss. There is, however, much peat land that might at once be profitably reclaimed, especially where the owners already live upon it or where it forms parts of farms consisting largely of mineral soil. In general the wise method of procedure appears to be for those men already living upon farms which have more or less peat land, either already provided with, or convenient to outlets, to try out at once the complete reclamation of a few of these unprofitable acres, making use of modern methods.

PEAT INDUSTRY REFERENCE BOOK.

By Fred T. Gissing.

Published by J. B. Lippincott, $3.00.

Since the conditions existing by the war have considerably increased the price of our commodities, the possible industrial uses of peat have become far more formidable than heretofore.

This pocket book entitled "Peat Industry Reference Book," by Fred T. Gissing, is a welcome contribution to the industry. When an industry can afford to have a reference book of its own we feel that it is getting on its feet and is becoming an economic factor in a nation's life. This is just as true in the North American Continent, in some cases more so, as in England.

This reference book contains a fund of information and is supplied with the more recent scientific data available on the subject, and contains digests of the work done in most countries of the world. Although work accomplished in one part of the world is not always applicable to local peaters, yet there is no doubt that the knowledge of what has been done and said

on peat in other parts can be made use of so far as they are applicable to individual deposits, and peat engineers will find this publication a suitable addition to their library.

HERBERT PHILIPP.

FUEL ECONOMY IN SWITZERLAND.

The securing of an adequate fuel supply is not last among the great economic problems of Europe. Coal-producing countries like England, France, Belgium, and Czechoslovakie are producing much less than enough coal for domestic use, while the other countries which are chiefly dependent on importation for their fuel find themselves in a situation that is extremely serious. As a consequence all the European Governments are giving the problem of coal supply their most careful attention. They are endeavoring not only to increase local production, but are seeking ways of more economically using the fuel that is at hand. Some of the Governments are taking steps to secure an increased importation of coal.

The latest available statistics show a decrease in Germany's coal production from 190,000,000 tons in 1913 to 116,-500,000 tons in 1919. The production of lignite, however, has increased somewhat, being 87,000,000 tons in 1913 and 93,-000,000 tons in 1919.

The local production of coal in Switzerland is negligible. The hopelessness of any real coal mining was demonstrated by the expensive boring tests made during the war. It appears improbable that the exploitation of the meager seams of slaty anthracite and lignite, rediscovered during this period, will outlive the normal importation of coal of good value. The relative importance of the imported and domestic fuels, during the last year of the war, may be fairly estimated from the quantities in Zurich in 1919 as shown below:

		Quantity.	Equivalent in terms of coal. Tons.
Coal and coke	Tons	63,230	63,230
Briquets	Tons	3,000	1,500
Firewood	Cubic meters	60,000	11,500
Peat	Tons	8,000	2,660
Slaty anthracite	Tons	1,600	800
Lignite (brown coal)	Tons	3,000	750
Total			80,440

A number of Swiss cities or communes have communal forests and derive considerable income from the sale of firewood. The city of Zurich, for example, owns a communal forest of 2,800 acres that yields an income of about $20,000 a year. But the use of firewood has now reached double the normal amount and it is feared that nothing more can be done in this direction without serious injury to the forests.

The total annual consumption of coal in Switzerland, in normal times, is about 3,000,000 tons. But this amount decreased during the greater part of the war period. Following is the coal importations for those years:

	Tons
1914	3,107,896
1915	3,311,442
1916	2,151,523
1917	2,269,872
1918	2,141,399

Formerly, the greater part of the coal came from Germany. The source of the imported coal, coke, etc., from 1914 to 1918, is stated in terms of the percentage of the total amounts in the following table:

	1914	1915	1916	1917	1918
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Germany	87.84	91.56	86.68	90.46	86.08
Belgium	2.99	7.57	12.56	7.03	5.98
France	6.51	.33	.31	1.26	4.24
Great Britain	1.03	.02	.02	.77	2.41
Austria	.41	.07	.42	.48	1.29
Holland	1.11	.40	.01	....	....

Owing to the expiration of the German-Swiss coal agreement in December, 1919, the importation of coal from Germany has greatly diminished during the last year. But a commercial treaty with France has just been effected by which France will allow the exportation of 20,000 tons of coal per month to Switzerland in exchange for certain electric power and certain Swiss products.

Within recent months Switzerland is placing more and more dependence on England and America for its coal supply. The following table of importations for 1919 shows that it was not until July of that year that Switzerland began importing coal from the United States, but that the importation at once became very important:

Countries of origin.	Jan'y Tons	Feb'y Tons	March Tons	April Tons	May Tons
Germany	44,904	60,646	57,800	31,236	39,775
Belgium	2,833	60	13,290	52,194	91,128
Alsace	....	3,229	1,543	3,646	5,838
France	6,255	.....	.....	2,000	1,716
Austria	366	.....	.....	704	1,054
England	4,862	.....	.....	.....	.....

Countries of origin.	June Tons	July Tons	August Tons	Sept. Tons	October Tons
Germany	41,820	71,156	57,500	42,177	50,604
Belgium	60,316	70,332	42,348	33,703	16,224
Alsace	3,304	3,977	3,245	2,379	1,782
France	3,902	2,691	1,863	1,541	3,238
Austria	509	800	389	540	10
England	6,359	25,936	17,050	6,713	11,060
United States	....	24,857	139,731	65,847	59,309

The most recent statistics at hand show the importations of coal for the month of March, 1920, as follows:

	Tons
Saar Valley	17,522
Ruhr District	14,928
Belgium	18,865
France	3,454
England	47,113
United States	29,118
	131,000

The importation of coal in Switzerland has now been centralized, being effected exclusively by the Swiss Coal Association at Basel. Since Switzerland has come to rely chiefly on the United States for coal, this coal association has at the Swiss Legation in Washington a purchasing department charged with the purchase of coal and securing freight space for same.

As the amount of coal obtained from abroad is still far short of present needs, there is yet no talk of doing away with the system of rationing the coal supply which has been in force during the past three years.

The difficulty in obtaining an adequate supply of coal and the high prices paid for what is obtained have naturally led to the adoption of means for its more economical and efficient use. Governmental inspection of public and private buildings

showed that too little attention had been given to the selection and installation of heating systems, and that the location of chimneys, fireplaces, etc., were not always well chosen. Efforts were made wherever possible to correct this state of affairs. In the case of large dwellings and apartment houses making use of a central heating system, it was suggested that the rooms in more constant use be supplied with chimneys and stoves so that in milder weather only those rooms need be heated.

The coal shortage has led to a considerable development of hydro-electric power stations. At the outbreak of the war the Swiss power stations had at their disposal approximately 526,000 horsepower yearly average. Despite the unprecedented rise in the cost of labor and the materials for electrification, the construction of power stations goes steadily forward. It is estimated that the water power which is immediately available in Switzerland is approximately 1,189,000 horsepower. It is now seriously proposed to electrify the Swiss railway system, a project that would require 245,000 horsepower.

The stress occasioned by the coal famine has led to the use of electricity for heating as well as for power and lighting. In particular, electrically produced heat is now being used on a large scale for cooking. Thus, in Zurich a very considerable saving of coal was effected by the electrification of bakeries. At the present cost of coal and wood the hydroelectric plants supply the bakeries electricity at a price more favorably than that for which coal or wood could be furnished. For producing 100 kilos of bread there is used on an average 20 kilos of coal at the present cost of 4.05 francs. An electrically heated oven uses for the same amount of bread about 80 kilowatt-hours. At a price of 3 centimes per kilowatt-hour for the night current, the electricity costs only 2.40 francs. Even the day current can be used in successful competition with the coal-heated ovens. At the time the city reported on this matter about 37,000 kilos of bread per day were being baked, so that a saving of 370 tons of coal per month was effected. The present demand for the installation of electrically heated ovens is considerably in excess of the ability of the firms to supply them.—(Consular Report.)

ELECTRIFICATION OF GERMAN RAILWAYS NEAR CITIES.

Coal as a power producer will be replaced so far as possible by the use of peat and the electrification of railroads in the

vicinity of the large German cities. Great hopes are being placed on the new Theissen 10,000-horsepower vertical gas turbine, two of which have been ordered for use on the German railways. It is hoped that they will be able to replace the coal-burning locomotives.

In regard to the electrification of the German railways near large cities, it is planned to install large central power houses, which will be equipped with peat-burning furnaces. The peat bogs in the vicinity of Osnabruck will furnish this fuel. Machinery for the working of this peat has been installed, and it is hoped that the first deliveries will take place by September 1, 1920. Experiments are being made by the German Government with machinery for pressing the peat, so that it may be transported economically.—(Commerce Reports.)

PEAT PRODUCTION IN NORWAY.

Smolen Island, near Kristianssund, N., is a flat spot of land possessed of immense areas of peat bog. It is doubtful whether there is anywhere a better location for the production of peat in large quantities.

Some time ago a company was organized under the name of "Smolen Co." It owns large areas on the island, and has a modern plant with six large machines for preparing the peat for market, after which it is transported on tracks down to the company's wharves.

It is expected that 30,000 tons will be produced this year, increasing till production reaches 50,000 tons a year. The principal market for this is Kristianssund, but the surrounding territories are also glad to get peat for fuel since coal and coke command such exorbitant prices.

Even a coasting steamship company serving the local trade in that vicinity has used peat for its steamers, enabling them to keep up their routes to full extent, while other local lines had to reduce their sailings because of the coal situation.

The "Smolen Co." intends also in the near future to extend its business to the manufacture of coal briquets for use by steamers and factories. The nature of this product, as it affects the cost of handling and transportation, will of course widen the territory naturally tributary to this local source of fuel supply.—(Consular Report.)

DETERMINATION OF GRADE OF PEAT.

G. Keppeler.

The degree of conversion to peat of mosses can be determined by decomposing the material by 72 per cent. sulphuric acid. The polysaccharides pass into solution, and the sugars can be estimated by tiration with Fehling's solution. The dextrose estimated in this way, and calculated on the water and ash-free peat, is termed the "total reduction." The maximum possible value is 68 per cent., so that if the "total reduction" for any peat be g, then $100 - g \times 100 + 68$ is a measure of degree of conversion of the original vegetable matter into peat. This value is called the "degree of decomposition." The degree of conversion to peat may also be estimated from the residue after treatment with 72 per cent. sulphuric acid. From this residue (referred to 100 parts of organic matter) the ash and also the residuum left in the acid treatment of sphagnum moss (11 per cent.) are deducted in order to obtain the degree of conversion." The newer moss peats generally show a low "degree of conversion," scarcely 30 per cent., whilst the older ones give a much higher value, up to 50 per cent.

VARIOUS FERTILIZERS MADE FROM PEAT.

B. Tacke.

The analysis of the special fertilizer made from peat was:

	Per Cent.
Mineral Matter	9.8
Nitrogen	1.5
Lime	12.7
Phosphoric Acid	0.55
Potash	0.6

Another fertilizer, "humus-silicic acid" (Humuskieselsaure), was employed. It analyzed:

	Per Cent.
Mineral Matter	30
Nitrogen	0.9
Lime	1.5
Phosphoric Acid	0.2
Potash	0.34

To pot cultures of oats in sand were added one of the special fertilizers and additional potassium phosphate and limestone. The Nitrogen content of the cultures were based on

100 kg. nitrogen per hectare. The nitrogen in the special peat fertilizer is not readily available to the oat plant.—(Mitt., 1919—Vol. 36, p. 369.)

EFFECT OF AREATION IN LIME REQUIREMENT OF A MUCK SOIL.

Seth S. Walker.

Air-drying a black muck soil increases the lime requirement. The increase in lime requirement was less in a stored moist portion than in a water-covered undisturbed portion. The lime requirement of stored moist samples increased, but of stored dry samples decreased. Soil neutralized with limestone and stored moist showed a greater increase in lime requirement than unneutralized soil.—(Soil Science, 1919—Vol. 9, p. 77.)

DEVELOPMENT OF KAURI GUM INDUSTRY IN NEW ZEALAND.

Since the close of the war more attention has been given to the development of the kauri-gum industry in New Zealand than any time during the past five years, with the result that it seems probable that greater quantities of kauri-gum and its by-products will be produced than heretofore.

Oil from Kauri Peat Swamps.

There are very extensive kauri peat swamps in New Zealand that have been placed at the disposal of interested parties by the New Zealand Government on a leased basis. The present area for which the Governor General by order in Council may set apart for the development of this industry is 10,000 acres on a basis of leases for 42 years, with no party to receive a lease exceeding 3,000 acres. The leases have to pay a low rental and also a royalty on kauri oil and other valuable products obtained.

The New Zealand Peat Oils (Ltd.) have taken one grant of 3,000 acres, and are now developing it with reasonably good prospects of success, having tested four samples taken from different depths of the swamp which yielded an average of 29 gallons of crude kauri gum oil to the ton, with a yield of 4,300 cubic feet of gas per ton. This company proposes to push the development of this industry during the coming year.

Kauri Gum Extraction and Grading.

A new method of gathering and grading kauri gum has lately been undertaken, whereby kauri peat swamps that are thoroughly pregnated with kauri gum in different stages of decomposition can be worked with reasonably good success, according to late reports. It is claimed that if this process succeeds, as indicated at present, there can be more kauri gum secured from the deposits in the North Island than has been secured to date, though of an inferior grade to that which has been gathered.

It is proposed to grade this kauri gum into about three or four grades according to size, which means largely according to the degree of decomposition. It is claimed any grade would be sufficient in quality for the manufacture of the lower grades of varnishes and similar products, and would be exceptionally good for the manufacture of linoleums and that line of goods; and it is expected that these qualities of kauri gum can be produced in such quantities as to be sold for a very much more reasonable price in proportion to what kauri gum has been sold for heretofore.

Production of Kauri Gum.

The production of kauri gum during the seven years previous to the beginning of the war averaged not far from 8,000 tons per year, while since that time it has scarcely averaged 4,000 tons, and during the year ended March 31, 1919, only amounting to 2,338 tons. Of the output of 8,473 tons for 1914 the United States took 4,531 tons, the United Kingdom 3,335 tons, Germany 373 tons, and the remainder was well scattered over 10 other countries; while for the year ended March 31, 1919, the United States took 1,371 tons of the 2,338 tons, while the United Kingdom took 346 tons, Canada 572 tons, and Australia 49 tons.

Of late quite large quantities of kauri gum have been going forward to the United States as shipping space could be obtained, and there are still large quantities in hand here for export, and it would seem there would be no difficulty in getting all of the kauri gum necessary from now on.—(Consular Report.)

NEW ZEALAND KAURI-GUM INDUSTRY.

Interesting comment appears in the April issue of the Auckland Weekly News upon the revival of the kauri-gum industry in New Zealand, tracing the pursuance of gum digging

back to 1868, from which time to 1886 the yield of the gum-bearing lands in the northern Province amounted to from 2,000 to 4,000 tons annually, obtained by the most primitive methods. This increased in the following 20 years to an average of 8,000 or 10,000 tons, which gradually declined until in 1916 and 1917 between 4,000 and 5,000 tons were obtained. The gum-bearing swamps are the site of ancient kauri forests, in which the deposits of gum are added to by the constant shedding from the kauri tree of its bark scales and leaf stems, on which little beads of gum have formed. Heretofore that obtained by digging, grubbing, hooking, and tree-climbing was all such as could be readily seen and handled, ranging from pieces the size of a nut to those weighing over 100 pounds. Now it is realized that in certain classes of soil gum also exists in a very fine state of division, and it is proposed to work this soil scale by mechanical appliances.—(Commerce Reports.)

NEW ZEALAND KAURI-GUM PRODUCTION.

The production of kauri-gum during 1919 fell short of the output for many years, due principally to the shortage of labor, together with the disorganized condition resulting from the war and the effort made to put the industry on its feet again.

During the year steps were taken to put into operation a new method of extracting kauri-gum by means of machinery instead of by the old hand processes. This new process grades the gum according to sizes, and it is claimed will save or gather more of the smaller particles of the partially decayed gum than any method that has been in use. By this process much kauri-gum that has been lost will now be saved for the manufacture of linoleums or put to other lower-grade uses. It is claimed that the industry will become increasingly profitable and will supply greater quantities of kauri-gum at cheaper prices than any process yet known.

The production of kauri-gum during the seven years previous to the beginning of the war averaged about 8,000 tons per annum, while since that time it has averaged scarcely 4,000 tons. The production for the year ended March 31, 1919, was 2,338 tons, of which the United States took 1,371 tons, the United Kingdom 346 tons, Canada 572 tons, and Australia 49 tons.

During the year the New Zealand Peat Oils (Ltd.) further developed their process for extracting oil from kauri peat swamps with good results. This undertaking has the approval and backing of the New Zealand Government, and promises much for the kauri-gum industry of the Dominion. The com-

pany has been granted a lease on 3,000 acres for 42 years, for which the leases pay a low rental and a royalty on all kauri oil and other valuable products obtained. The company has secured an average yield of 29 gallons of crude kauri oil to the ton of earth treated.

The New Zealand Government has set aside $4,866,500 to be devoted to repairing the worked kauri-gum lands suitable for settlement, and to assist in bringing these lands under cultivation where it is thought practicable. Where such lands are not suited to cultivation. Sir David Hutchins, Chief of Forestry in New Zealand, suggests that kauri forests might be planted which would become more imemnsely valuable to the Dominion, both for lumber and for the gum as well. It is estimated that 2,000,000 acres of such kauri forests, after 100 years, would produce an annual income of $24,442,500.—(Consular Report.)

PEAT OCCURRENCES.

Anaheim Area, California.

The Anaheim area comprises the most important agricultural sections of Orange County, California, and its northern and northeastern extension small parts of the adjacent counties of Los Angeles and San Bernardino. The area lies southeast of Los Angeles and fronts on the Pacific Ocean for a distance of about 22 miles, extending inland a maximum distance of about 25 miles. Its average width from east to west is about 24 miles and its average length from north to south about 25 miles.

The surface soil of the muck and peat areas occurring in this survey is for the most part a black muck, consisting mainly of organic matter but carrying small quantities of silt or other fine mineral sediments. Below a depth of 15 or 18 inches this black silty mass usually contains more distinct layers of mineral material of grayish color, alternating with layers of peat, the entire mass generally extending to a depth of more than 6 feet. The material when dry is very light and will float on water.

The surface material is very friable and holds large quantities of water. The subsoil is often more porous, fibrous, and spongy, and generally contains undecayed roots of plants. It may contain some calcareous material, but as a whole it is practically free from alkali. Much of the muck and peat in this area is similar to its typical occurrence elsewhere in the Pacific coast region, but it includes some variations, owing to the fact that its areas are small and thus more easily modi-

fied by local influences. The greater part occupies small, usually elongated areas on flats affected by springs and seepage water, while parts of some areas lie at the foot of the bluffs of the old coastal plain deposits and receive seepage from higher areas. The depth and the relative quantity of the accumulated organic material present vary greatly, being shallower and containing more mineral matter where the areas merge with other soils. Some of the areas, such as those near Talbert, are covered with several inches of recently deposited mineral matter, similar to that composing the soils of the Hanford series.

Muck and peat occurs only in the southwestern part of the survey. The two largest bodies lie southwest of Wintersburg and southeast of Paularino. Several other bodies are mapped near the Springdale School and a narrow area occurs near Talbert. Small bodies are encountered east and west of Smeltzer and east and north of Alamitos Bay.

Much of the muck and peat is similar in topography to the alluvial types with which it is associated. Some of the bodies occupy slight depressions, while others lie on slight ridges or hummocks and are distinct from the surrounding alluvial soils, above which they have gradually been elevated by the accumulation of decaying plants. The areas of muck and peat have a high water table, but are rarely overflowed. Most are tile drained and the water table is kept at a sufficient depth to permit the growing of shallow-rooted crops.

Owing to its small extent muck and peat is not of great importance. Practically all of it is cultivated, mainly to truck crops and sugar beets. It is considered well adapted to the truck crops, but growers say that the saccharine content of the beets is low, although the crop produces very good yields. The handling of this soil is very difficult, as it is frequently unstable and will not support the weight of work stock. Owing to the great amount of water present it warms slowly, but crops do well without irrigation. Because of the diversity of crops in small plantings it is difficult to give an estimate of production, but yields usually are heavy.

Muck and peat is usually sold in conjunction with other soils and the price depends largely upon that of adjoining land. The price frequently reaches $400 to $500 an acre.

Lower San Joaquin Valley, California.

The reconnoissance soil survey of the Lower San Joaquin Valley covers an important part of the physiographic division known as the Great Interior Valley of California, which occupies the central part of the state. This latter valley is al-

most 500 miles in length with an average width of between 40 and 50 miles, and extends in a general northwest-southeast direction from the city of Redding on the north, in latitude 40° 35, southeastward to south of Bakersfield, or about latitude 35° 10.

The group muck and peat consists of brown, dark brown, or black soils, in which the decayed and semi-decayed roots and stems of tule and other aquatic plants constitute a large part of the material. This organic material is mixed with mineral matter, which varies from a negligible quantity in the most typcial areas to relatively large quantities where the crop merges with alluvial soils. The typical areas have the peculiar spongy and more or less fibrous structure and texture which are characteristic of muck and peat material. The nature of the soil depends largely on the stage of decomposition of the organic material. Where it is slightly decomposed the soil is brown and fibrous, and is less desirable for agriculture than where the material is well rotted. The latter is black in color and of fine texture and friable structure. Under natural conditions the fibrous material breaks down into the decomposed muck, and it is the aim in reclaiming these lands to hasten the decomposition of the coarser material.

In these areas which have been brought under cultivation the surface soil is sufficiently coherent to bear the weight of work stock and of specially devised farm machinery, but the underlying material is in a soft, semi-floating condition, and lacks coherence or the ability to sustain any considerable weight. This surface crust is flexible and gives under the weight of pedestrians and very noticeably undulates with the passage of teams or farm machinery. Below the surface the decomposed muck becomes less coherent until the semi-floating, saturated, coarse peat is reached, usually at a depth of 1 to 3 feet. It is generally possible to force the handle of a hoe or pitchfork through the surface and, with the slightest pressure, into the ground to its full length. The soil material is very light in weight, and much of it will float.

The character of this soil material is very favorable to agriculture in many features. It never puddles, and yet has a high water-holding capacity. When the material becomes ignited, however, it burns, and there remains only a bed of ash full of pits or holes.

Much of the material of this crop varies from the typical in containing large quantities of sediments, in places more than half the soil mass. In some places these sediments have been deposited over the surface, while in others the typical muck or peat is but a shallow layer over the mineral or alluvial

material. These variations occur along the margins of the typical areas; they are absent in the central islands of the San Joaquin delta region, in which the muck and peat material occurs. The nature of the soil in these modified areas depends on the proportions of the organic and mineral constituents. An increase in mineral matter makes the material heavier and alters the capillarity of the soil and its moisture-holding capacity.

Muck and peat in the marginal localities is less than 15 feet deep, but it is of much greater depth over broad areas. It is underlaid by varicolored sediments. Conditions in the marginal areas are too variable for accurate description. Silts and clays may cover a part of the surface or entirely displace the organic material at varying depths below about 2 feet. Gravel is absent in the soil column, but strata or sand or fine sand are sometimes encountered.

This group of soils covers the region known as the river delta, an extensive area of low elevation around the lower course of the San Joaquin River to the west of Stockton. It adjoins a body of similar character which occurs along the lower Sacramento River and is mapped in the reconnoissance soil survey of the Sacramento Valley. The two bodies make up a geographic and agrucultural unit, and together are known as the "Delta Lands" or the "Island country." The region is marked by a flat topography and in its virgin state is very poorly drained or covered with water. Originally it was a tule marsh, inundated by the waters of the rivers and smaller streams. Numerous winding channels divide the region into islands of a few hundred to several thousand acres.

Utilization of these soils is dependent upon their reclamation. This is done by building protecting levees around the islands and draining them by means of pumping. Much of the surface of the reclaimed areas is below water level in the surrounding channels and is often below tide level, so that the areas are without natural drainage. The most general system for controlling the water is to supply irrigation water through gates in the levees by siphons or pumps, drainage being effected by pumping the water back into the streams. The land is sub-irrigated, the water being allowed to flow through ditches about 2 feet deep and 60 to 80 feet apart. This method is very successful on these soils. The marginal areas, where the soils consist largely of mineral material, are subject to accumulations of alkali.

The reclamation of the muck and peat lands has generally been accomplished through the organization of reclamation districts. The earlier work was quite expensive, but the use of

improved machinery to build the levees has materially reduced the cost. Difficulty is sometimes experienced through settling of levees, and frequently they require building up and strengthening.

The soil of this delta region has become one of the most widely known in the state, because of its remarkable productiveness of certain special crops. Large expenditures have been made for reclamation and the extensive areas rendered tillable. They are devoted largely to the production of asparagus, potatoes, beans, onions, and celery. Rotation is essential, especially for potatoes, and barley, clover and other crops are grown for the purpose. Alfalfa is not grown extensively, owing to the high water table, a condition unfavorable for this deep-rooted crop. Corn yields heavily. The large amount of manual labor required in producing the crops is performed principally by Chinese, Japanese and Hindus.

Dairying is a very important industry on muck and peat, but is best developed on the marginal portions of the group, where the water table is lower than the average. Many sheep are pastured on these lands after the crops are harvested.

Some of the islands are accessible only by water, and water transportation is available for nearly all the area. Much of it is well supplied with good roads.

Santa Maria Area, California.

The Santa Maria area includes the northwestern part of Santa Barbara County and the southwestern part of San Luis Obispo County, Cal. It is about 60 miles northwest of Santa Barbara. The area is bounded on the west by the Pacific Ocean and on its other sides by low mountains. It comprises a total of 296 square miles, or 189,440 acres.

Peat consists of brown, fibrous, partially decayed vegetable matter, with only a small admixture of mineral material, 1 foot to 2 feet deep, and usually underlain by black, fine-grained muck more completely decayed material or muck. The subsoil may extend to a depth of 6 feet or more, although it is generally underlain at depths of 2 to 4 feet by sand.

Peat is formed mainly from the decay of the stems and roots of various water-loving plants, in this area largely grasses and segdes, with some tule (cat-tail, and willow). The surface is rough and uneven because the grasses have grown largely in tufts.

Only one body of peat is recognized in the area. This, which is of comparatively small extent, lies in the western part of the area south of the Santa Maria River and not far from the ocean. It occupies a shallow, basin-like depression,

which originally was without drainage, and subject each year to overflow. The area is now being reclaimed.

It is reported that a considerable deposit of peat at the lower end of the Arroyo Grande Valley was at one time reclaimed and farmed, but at present it is under water or very marshy.

Hillsborough County, Florida.

Hillsborough County is situated in the west-central part of the Florida Peninsula. It is bounded on the north by Pasco and Polk Counties, on the east by Polk County, and on the south by Manatee County. Pinellas County borders the county on the west for a distance of about 12 miles south of the north county line. The remainder of the western boundary follows a curved line drawn through the middle of Tampa Bay.

Muck consists of a deposit formed mainly of more or less thoroughly decomposed vegetable matter, with a considerable admixture of sand, silt, and clay. It has originated from the growth and decay of vegetation in the presence of water. Muck extends to depths ranging from 8 inches to several feet, the average depth being between 18 and 24 inches. It is black when moist and dark brown when dry. The materials are finely divided and when moist the soil is more or less plastic. In places there is a surface mantle, 1 to 4 inches deep, of coarse material consisting of recently accumulated vegetable matter. Quite frequently there is also a coarse, fibrous layer of peat or peaty muck overlying a substratum of fine sand, the upper part of which is black, grading into nearly white, fine sand. This fine sand is compact and generally water-soaked.

Muck is scattered throughout this county, occurring in basin-like depressions in the flatwoods, in the rolling uplands, and along streamway depressions. Its total extent, however, is small. The areas are covered by water most of the year and are known as "bays" or "hammock swamps." The native vegetation consists mainly of cypress, gum, swamp maple, water elm, oak, magnolia, red bay, cabbage palmetto, and myrtle.

As the expense of clearing and draining muck is large, only a small part of it has been brought under cultivation. When cleared and drained, it is suited to a wide variety of garden vegetables, including celery, onions, cabbage, and lettuce. Large applications of fertilizer are required for all crops, and the soil is generally in need of lime.

Some of the muck areas in the vicinity of Tampa, which grade into the Portsmouth fine sand, sell for $1,000 or more an acre when cleared and brought under cultivation. The under-

cleared areas range considerably in price, depending upon the location.

The material of the prairie phase of muck is similar to that of the typical or hammock areas. The immediate surface is frequently fibrous or peaty, and also the lower part of the mucky section. The mucky material overlies fine sand and is itself quite sandy in places, the sand having been blown in from the surrounding land. The depth of the material ranges from about 8 inches in the margin of the areas to several feet in the center, the average depth being greater than that of the hammock areas. Including with this phase are some spots of peaty muck and of brown, fibrous or non-fibrous peat, which are too small to separate on the map.

The prairie phase of muck occupies depressed areas representing filled-in ponds and lakes. It is mainly confined to the eastern part of the county, the most important areas occurring in the vicinity of Plant City. The vegetation consists of saw grass, pond lilies, rushes, sagittaria, and other aquatic plants. The areas are covered with water a large part of the year.

Very little of this phase is under cultivation. If drained, it would be a valuable soil for truck crops. In its undrained condition its best use is for pasture.

Peaty muck consists of a cumulous deposit of decayed vegetable matter in a less advanced stage of decomposition and containing less mineral matter than muck. In part it is a mixture of muck and peat in separate layers or masses, and there is consequently considerable variation throughout the type. The color ranges from black to dark brown or rusty brown, the more mucky material being the darkest colored. The brown material usually is coarse and fibrous, approaching the character of peat, but it may be finely divided in spots. The black material is only slightly fibrous. The depth of the material ranges from about 10 inches to several feet. Over most of the type, however, a compact, water-soaked, gray to white fine sand is encountered within the 3-foot section, generally at a depth of about 24 inches.

Peaty muck occurs throughout the county. Most of the areas are small, occupying depressions in the flatwoods and in the higher rolling sections. Some of the areas are connected by stream-way depressions which afford some drainage when the water is high, but as a rule water stands on the surface a large part of the year. In many places the surface is uneven, owing to the formation of hummocks around tree stumps or the burning out of the more peaty spots in dry spells. The vegetation in some of the areas consists almost exclusively of

cypress, while in others there is a mixed growth consisting mainly of cypress, gum, red bay, magnolia, swamp maple, and myrtle, with a carpet of sphagnum moss. When the growth is mixed, it is usually thick.

Owing to the expense involved in clearing and preparing this land, very little of it is cultivated. Some areas near Tampa have been drained and are devoted to truck crops. The newly cleared land usually is too raw for celery, although some good celery has been grown on it. It is better suited to such crops as tomatoes and potatoes. The more peaty spots dry out quickly and crops suffer greatly for moisture.

The soils require large applications of commercial fertilizer, and stable manure is highly beneficial. The structure of the soil material in cultivated areas is improved by sand washed into it from other soil types.

The value of the areas of peaty muck varies considerably, depending upon location and drainage possibilities. The price ranges from $10 to several hundred dollars per acre.

Peaty muck, prairie phase, consists of a variable mixture of mucky and peaty material of black to rusty-brown color. It is usually somewhat fibrous, and ranges in depth from 10 inches to 7 feet or more, but as a rule the underlying compact gray sand is encountered at 24 to 30 inches.

There are a number of acres of this phase, ranging in size from a few to several hundred acres, the largest occurring in the central part of the county. They represent shallow ponds and lakes which have been gradually filled by the growth and decay of vegetation. These areas are inundated most of the year, and in places through the year. Some of them are covered with saw grass, with a lily pond here and there, and others support a growth of rushes, sagittaria, and various water-loving grasses and sedges.

This phase is of little value for agriculture, and only a small part of it has been put under cultivation. Its main use is for grazing. The largest cultivated areas are in the vicinity of Mango Lake. These have been drained and fitted with means for sub-irrigation, and are successfully used for the production of truck crops, mainly celery, snap beans, potatoes, sweet corn and lettuce.

Large quantities of commercial fertilizer are used. For celery 1 ton or more per acre is used, a large initial application being made, with side applications as needed. Where the phase is cultivated, sand has been hauled in and incorporated with the soil. This not only improves the texture of the soil, but makes it firm enough to hold the weight of animals; otherwise muck shoes have to be used on work stock.

There are several bodies of this phase convenient to railroads that could be profitably drained and cultivated.

Swamp includes low-lying areas bordering streams and covered with water all or most of the year. The soil material is extremely variable in color, texture, and structure, but is usually of a mucky to peaty character.

The large areas of swamp occur along the Hillsborough River and in its branches. Some of the areas were formerly flatwoods and have been formed by the damming of the Hillsborough River. The area lying between Harney and Lake Thonotosassa was largely formed by the building of a dam above Sulphur Springs.

Swamp is non-agricultural, and is valued only for the cypress timber it supports. Its reclamation would be very difficult.

Porter County, Indiana.

Porter County, Indiana, is located in the northwestern corner of the state, about 40 miles from Chicago. It is bounded on the west by Lake County, on the south by Jasper County, from which it is separated by the Kaukakee River, on the east by Laporte County, and on the north by Lake Michigan.

Muck consists largely of decayed remains of marsh grasses and mosses. Usually it is very mellow, black vegetable mold to a depth of 3 feet or more. Sometimes decomposition has been retarded and brown, peaty, fibrous layers occur in the subsoil. Usually the deposits are from 3 to 10 feet deep. Variations occur in which the muck contains a relatively large admixture of sand and clay. In some areas the layer of muck is shallow and sand or clay is encountered within 18 to 36 inches of the surface.

The muck is scattered through various parts of Porter County. The areas occur within bodies of glacial, glacial-lake, and outwash deposits. Some of the largest areas lie northeast of Furnessville, in the Calumet valley north of Crisman, south of Chesterton, around Canada Lake, and in the glacial outwash channels south of Valparaiso and Coburg.

The topography of much of the muck is flat, but frequently is occupies a rather high position along the sides of depressions and stream channels. Such areas are due to the springs that issue from sandy strata and keep the hillsides in a saturated condition favorable to a luxuriant growth of vegetation.

In its natural condition the muck was water-logged most of the time, and many areas are still very wet. However,

ditching has reclaimed the greater part of the areas, and more of this land is brought under cultivation each year.

Corn is practically the only crop grown regularly on the muck. In the shallower areas oats are sometimes grown. A few small fields are devoted to potatoes and millet. Marsh hay is cut from some muck land, but a part of it is too hummocky and wet for any use except pasture. Corn on well-drained muck yields 30 to 60 bushels per acre, but the quality is not so good as on the upland soils and the crop is sometimes injured by early frosts. Oats do well, but are likely to lodge.

Little use has been made of any kind of fertilizer on this land, as it is new and very productive. Potash has a beneficial effect in increasing yields and improving the quality of the grain.

Although muck lands were worth very little before drainage operations began, they are now held for $100 or more an acre.

Most fields of muck need thorough drainage. Straw and ashes from wood or corncobs may be used to advantage for the potash they contain. The production of special crops, such as onions, potatoes, peppermint, sunflowers, etc., has been profitable on such land in other localities.

Blackhawk County, Iowa.

Blackhawk County is situated about midway between the center and the northeastern corner of Iowa. Waterloo, the county seat about 80 miles northeast of DesMoines. The county contains 565 square miles, or 361,600 acres.

Muck represents areas in which the soil consists of black, finely divided organic material derived through the slow decomposition of aquatic vegetation in shallow water, or under such conditions that saturation has been almost continuous. It occurs mainly in old ponds and lake beds, but not infrequently in seepy hillside areas.

Small developments of muck occur in various parts of the county. The largest cover 15 to 20 acres. In most of the areas the organic deposit ranges in depth from a few inches at the margin to 3 or 4 feet in the center. Many small spots of shallow muck, consisting of clay loam with an abnormally high content of vegetable residue in the first few inches, are included in the Clyde soils.

Where the moisture content can be fairly well controlled, muck is well adapted to growing cabbage, onions, celery, mint, and a few other truck crops. Timothy and bluegrass do well, but the former makes a coarse, woody growth. Oats in some seasons give good results, but the crop often lodges badly or

fails to fill well. As much as 20 to 25 bushels of wheat, barley, or rye have been obtained on well-drained areas of shallow muck underlain by clay, but such yields are conditional upon a favorable season.

Clay County, Iowa.

Clay County lies in the northwestern part of Iowa, one tier of counties separating it from the State of Minnesota and two lying between it and the State of South Dakota. Its southwestern corner is about 60 miles northeast of Sioux City, the second largest city in the state. It is bounded on the north by Dickinson County, on the east by Palo Alto County, on the south by Beuna Vista County, and on the west by O'Brien County. It is practically square, and has an area of 563 square miles, or 360,320 acres.

The surface material of muck and peat consists of 6 to 24 inches of dark-brown to black, partly decomposed organic matter derived from water-loving plants and grasses, with a small admixture of silt, clay, or very fine sand washed from the adjoining slopes. Its average depth is about 12 inches. The underlying material is a nearly impervious, drab silty clay or clay. This is darker in the upper part, owing to the presence of considerable organic matter. The subsoil is highly calcareous. In a few places a yellowish-drab mixture of clay, sand, and gravel underlies the dark-drab subsoil at about 27 inches. Muck and peat differ only in the stage of decomposition of the vegetable matter. Muck is black in color, the vegetable matter is well decomposed and finely divided, and it contains considerable mineral matter, mostly of fine grades.

Muck and peat occurs in old sloughs or lakelike depressions whose drainage outlets have become obstructed in some manner and in which the decomposition of the accumulating plant growth has been retarded by subsequent deposits and by conditions of poor drainage. The material in many places is fibrous, retaining the structure of the plants. Many of the areas have been drained by the deepening of the drainage outlets. Areas where water still stands on the surface are indicated on the map by marsh symbols.

The four largest areas of muck and peat occur, respectively, southwest of Lost Island Lake, southwest of Webb along Montgomery Creek, in the west-central part of Lake Township, and in the bed of Mud Lake, in Sections 25 and 26, Garfield Township. The areas in Mud Lake and along Montgomery Creek have been recently drained by large ditches. Smaller areas of muck and peat occur over the eastern tier of townships. Patches too small to map lie in the Lamoure silty clay

loam in this part of the county. The surface of the type is practically level and the natural drainage poor.

Muck and peat cover a total area of 5.5 square miles, but probably less than 320 acres have been put under cultivation. About 10 per cent of the total area has been drained in the last two years, and projects are under way for draining of much of the remainder in the near future. It has been found that corn and small grains can not be grown as profitably at first as timothy and clover. Corn is usually stunted and the small grains are inclined to produce straw at the expense of the grain. The yields of timothy and clover are as high as those obtained on the upland soils, and in some cases higher. Most of the type where not too wet is used for pasture. It has been found that the best practice after draining this land is to seed it to grass and pasture it heavily for several years before sowing to grain crops. Pasturing the land with a large number of animals serves to compact the soil.

Practical methods for the improvement of shallow peat deposits in Northern Iowa, as suggested by the Iowa Agricultural Experiment Station, include thorough drainage, deep fall plowing to expose the soil to the effects of freezing, and the frequent cultivation during the summer to hasten decomposition.

Timothy and alsike clover are suggested as the crops best suited to the areas newly reclaimed. Experiments show that while the peaty material may be deficient in lime, potash, and phosphorus, there is sufficient in the subsoil to supply crops, and the application of commercial fertilizers has not proved profitable.

Yates County, New York.

Yates County is situated in the central part of western New York. On the east, Seneca Lake separates it from Seneca and Steuben Counties, on the south the county is bounded by Schuyler and Steuben Counties, and on the west and north by Ontario County. Yates County has an area of 343 square miles, or 219,520 acres.

Muck represents accumulations of more or less decayed organic matter in a very finely divided state, mixed with some mineral matter, and existing naturally under poor conditions of drainage. The depth of the muck ranges from 6 inches to 3 feet or more. It is very dark brown to black at the surface, and becomes distinctly brown with depth. At 20 inches or more the well-decomposed organic matter gives way to more fibrous material or peat. The underlying soil ranges from clay to sand and to gravel.

Muck is mapped in large and small areas in every town in

the county. The largest areas lie along Flint Creek in the town of Potter, and along West River at the head of Canandaigua Lake. The type everywhere is low and flat. It receives run-off from the surrounding higher line areas, and is naturally poorly drained. The two larger areas are swampy most of the year.

The timbered areas support sparse stands of elm, soft maple, black ash, cedar, tamarack, hemlock, and alder. Some areas are covered with reeds, cat-tails, rushes, sedges, and aquatic plants. A little hay is cut, and some pasturage is obtained. Ninety-eight per cent. of the type is undeveloped. Artificial drainage is essential before cultivation can be carried on.

Reclaimed areas of muck in the adjacent county of Ontario produce excellent crops of celery, onions, potatoes, cabbage, and hay. In production of these crops large quantities of commercial fertilizers and stable manure are used.

Oswego County, New York.

Oswego County is situated in the north-central part of New York, at the eastern end of Lake Ontario. It is bounded on the north by Lake Ontario and Jefferson County, on the east by Lewis and Oneida Counties, on the south by Onondaga County, and on the west by Cayuga County and Lake Ontario. Part of the south boundry follows the Oneida River from its junction with the Seneca east to Oneida Lake and the south shore of the lake to the eastern county boundary. The county includes a land area of 948 square miles, or 606,720 acres.

Muck consists of vegetable matter in varying stages of decomposition, mixed with small proportions of sand, silt, and clay washed in by overflow waters or carried by the winds from the surrounding uplands. The vegetable matter represents the remains of plants, more or less preserved by the water through its action in retarding oxidation. Part of the material included with this type really represents peat. Here decomposition is less advanced, and the material still retains a fibrous character and more or less the identity of the plants from which derived. In the typical muck areas the material is finely divided and all trace of the original structure of the plants from which it has come has disappeared. Peat is usually brownish in color and muck jet black. Muck has a slight plasticity due to the more finely divided condition of the material and to the admixture of same mineral soil particles.

The variations from well-decomposed and finely divided organic matter to the coarser, fibrous peaty material occur within short distances rather than in distinct large areas. The

various textures are intermingled on the surface, but below they are rather in layers, the lower material usually being more peaty. Frequently the immediate surface in the case of areas of recent accumulation has not yet become broken down. With cultivation the coarser materials soon change to a more or less finely divided state, but they still retain their brownish color.

The depth of the muck varies from a few inches on the border of the areas to several feet only a short distance away, and in some areas to depths beyond ordinary means of sounding. Some areas were included where the depth did not exceed 2 feet in any place, but in the main the organic layer is more than 3 feet deep.

Muck occurs in every town in the county, but the largest developments are through the central part, east and west. It occurs in a large number of areas varying in size from a few acres to several square miles. The largest area is that in West Monroe and Constantia Towns along Oneida Lake. The type is most extensive in Hastings and Palermo Towns and the southeast part of Mexico Town, where there is a series of bogs conected by narrow arms.

This soil occupies depressed areas or old filled-in ponds, and small lakes and stream valleys. The areas are frequently the boggy upper courses of streams. They lie at all elevations and can be drained by clearing their outlets and digging ditches. The only exception is the area along Oneida Lake. Here dams constructed to aid navigation raise the water so that the surface of the muck is barely above the water level. Water stands on the muck areas a good part of the year, although they are dry, as a rule, during the summer.

The vegetation is of water-loving species. In places it consists of cat-tails, rushes, sedges, and grasses, with pond lilies and other aquatic plants in the pools of water. The greater part of the type has a growth more characteristic of swamps. Such trees as swamp maple, elm, tamarack, hemlock, spruce, and scrub white pine may be abundant, and there may be a thick undergrowth of shrubs such as alder and high-bush huckleberry. As a rule there is a deep carpet of sphagnum moss. According to the predominant growth, the various areas are known as tamarack swamps, huckleberry swamps, alder swamps, etc.

Muck is an important soil in the agriculture of the county, although its utilization is confined to truck gardening. Only a small proportion of the type has been developed. On areas lying near the larger towns, as near Oswego, and especially Fulton, trucking has been developed and good markets

are available for the products. At the present time more distant areas are being cleared, drained, and developed. Several companies have taken over large bodies of muck for development.

The principal crops grown are lettuce and onions, with celery, beets, and carrots of somewhat less importance. The yields are good. A number of crops of lettuce are produced in one season, and it is consequently one of the most profitable crops. The variety known as Boston head lettuce is grown exclusively.

The crops are all heavily fertilized with a complete fertilizer, though at present, on account of the shortage of potash, this element is used in very small proportions. From 1,000 to 2,000 pounds of fertilizer is applied per acre. No lime is used. Litmus tests show that the muck is neutral or at least not acid.

Muck requires drainage to put it in condition for cultivation. Clearing is expensive, and preparing the seed bed is difficult until the land has been cultivated long enough for it to settle. In working this land it is necessary to use a special shoe (muck shoe) on horses to prevent their bogging. Small caterpillar tractors work well, and a number are in use.

Muck lands are becoming higher priced as the demand increases. Uncleared and undrained land which a few years ago sold for only a few dollars an acre now brings $50 to $100, where situated within reasonable distance of a railroad station. The use of auto trucks has been a large factor in increasing the radius of the area within which this land can be worked profitably. Developed muck land sells for several hundred dollars an acre. The heavy expense of clearing accounts in part for the high market value.

Meadow is a term applied to low-lying acres that are wet most of the time and in which the soil material is too variable from place to place to be classed as a definite type. As mapped in Oswego County, meadow includes areas of Caneadea, Granby, and papakating soils, as well as muck, but even under more wet conditions, being either swampy or semi-swampy. Some areas are covered by cat-tail rushes, with intervening small ponds containing such growths as pond lilies; there may be trees and shrubs here and there or the vegetation may change entirely to trees and shrubs, the growth typical of swamps. The growth is frequently quite thick, and consists of ash, swamp maple, hemlock, spruce, scrub white pine, tamarack, and alder, with willow and swamp huckleberry.

In towns of Constantia, Amboy, Albion, Williamstown, and Redfield, and to a less extent in other towns, the ma-

terial is spoken of as "peaty muck" or ooze. It consists of silty material with considerable black peat and some muck. This peaty muck mantel varies from a few inches to 24 to 30 inches in depth, and is underlain by gray or drab sand containing stones and bowlders. These peaty muck areas are always wet and "miry" and do not support the weight of stock or persons. The large area along Oneida River is marshy in places, but in general has a tree and shrub growth. Because of the preponderance of ash this area and similar ones are spoken of as "ash swamps." The soil is largely of the Caneada series, with mucky or peaty spots included. These peaty muck areas are due to obstructed drainage. Along the Oneida River the poor drainage results from the construction of dams and locks built to aid navigation.

In its present condition meadow is non-agricultural and of value only for grazing and for the timber growth.

Saratoga County, New York.

Saratoga County is located in the eastern part of New York. It is about 180 miles from New York City and 200 miles from Montreal, Canada, and is upon the main highway of railroad traffic between these two cities. It is bounded on the north by Warren County, on the east by Washington and Renssealear Counties, on the south by Albany and Schenectady Counties, and on the west by Montgomery, Fulton and Hamilton Counties. The Hudson River forms most of the eastern boundary and the Mohawk River the extreme southeastern boundary. It has an area of 823 square miles, or 526,720 acres.

Muck consists mainly of organic matter formed from the decomposition of vegetable remains under conditions of poor drainage. As mapped in Saratoga County it varies considerably in color, depth, and drainage. The surface mass is dark brown to black. The subsoil is browner and is usually less decomposed. The depth of the organic deposit varies from a few inches to several feet.

Muck occurs in numerous areas, varying in size from less than one acre to tracts of several hundred acres. The largest areas lie north of Lakes Lonely and Saratoga, along Bog Meadow Brook, Spring Run, and Fish Creek. Extensive areas are mapped in the towns of Greenfield and Corinth. The type occupies relatively low positions and is naturally wet and swampy during the greater part of the year.

None of this land is under cultivation. A few small areas have been cleared and are used for pasture or to supply coarse forage or bedding material. Practically all of the original timber has been removed, leaving a second growth of cedar, hem-

lock, ash, and elm. Some areas support only a rank growth of sedges, cat-tails, and rushes. If this type were drained, it could be brought under cultivation and made into the most valuable soil of the region. Muck soils are especially adapted to celery, cabbage, onions, and similar crops.

Mahoning County, Ohio.

Mahoning County is situated along the Pennsylvania State line in the northeastern part of Ohio, about 60 miles south of Lake Erie. It has an area of 427 square miles, or 273,280 acres.

Muck consists mainly of dark-brown to black, smooth, finely divided and well-decomposed organic matter, with which is mixed a small proportion of silt, clay, and fine sand. The depth of this organic deposit varies from 12 inches to 36 inches or more. Where it does not extend throughout the entire 3-foot section, a fine, sandy loam of a whitish color underlies it. As mapped, however, the mucky deposit is 3 feet or more deep except in a few local areas. Muck is the result of the decayed water-loving vegetation in poorly drained situations.

This type of soil occurs in rather small areas throughout the southern and eastern parts of the county. The largest area lies northwest of Greenford. It occurs as flat and depressed areas with practically no natural drainage.

Only an acre or two of this soil is cultivated to truck crops. The remainder is covered with cat-tails, brush, and other water-loving vegetation. None of this land is sold separately, but it can probably be bought for $5 to $10 an acre.

In sections of Ohio where muck has been drained and reclaimed, excellent yields of celery, lettuce, onions, and other truck crops are obtained.

Marion County, Ohio.

Marion County, Ohio, lies just northwest of the center of the State, 45 miles north of Columbus. It is bounded on the north by Wyandot and Crawford Counties, on the east by Morrow County, on the south by Delaware and Union Counties, and on the west by Hardin County. It is irregular in outline, but the boundaries follow straight land lines. The county has an area of 409 square miles, or 261,760 acres.

To a depth of 6 or 8 inches the material mapped as muck consists of black, more or less thoroughly decomposed organic matter, with which an appreciable quantity of mineral soil is mixed. This surface deposit is underlain by a gray or grayish-brown silt loam or silty clay loam streaked with bog iron. The

black mucky surface material is invariably shallow, rarely extending to a depth of more than 10 inches.

Areas of muck occur in Scott and Claridon Townships, in association with the Clyde soils, and apparently represent depressions where there has been a greater accumulation of organic matter. The surface is flat, and both surface drainage and underdrainage are deficient.

Owing to its small extent the muck in Marion County is relatively unimportant. Corn and truck crops are practically the only crops grown. Corn yields 75 to 80 bushels per acre. The muck areas are valuable for trucking.

This land ranges in value from $125 to $175 an acre, depending on its location.

No fertilizer or manure is applied. The muck is generally plowed in the spring. Almost all of it is drained by open ditches and tile.

Buena Vista County, Iowa.

Buena Vista County lies in the northwestern part of Iowa. It is in the third tier of counties south of the Minnesota State line, and on the west two counties lie between it and the Sioux River which forms the South Dakota State line. It is almost a square in outline, containing 16 townships, and has an area of 571 square miles or 365,440 acres.

Peat has been derived from the same material, and in practically the same manner, as muck. It is probable, judging from its situation, that in its earlier development peat was covered by water more continuously than muck. The distinction between the two types is the greater proportion of organic matter in peat and its slightly less advanced stage of decomposition.

The surface soil of peat, extending to a depth of 10 to 14 inches, is composed of over 35 per cent. of black organic matter, much of which is undecomposed so that the original plants may be distinguished, and the remainder of a mixture of a very fine sand, silt, and clay. Of the three last named, silt predominates, and the amount of very fine sand present is very small. The surface soil merges into a silty clay, which becomes heavier and more plastic with depth through the 3-foot section. Below 24 inches yellowish-brown and gray mottlings occur and below 30 inches gray predominates, with only slight yellowish brown mottling. Snail shells and some mussel shells are found on the surface and lime concretions generally occur in the subsoil. Both surface soil and subsoil are calcareous, giving a strong reaction with hydrochloric acid.

Much of the type is surrounded by a narrow margin of muck. The two types are so clearly associated that boundaries are in some cases arbitrarily drawn, and some areas of muck too small to be mapped separately are included with the peat. Several small spots where the organic soil has been burned occur within the areas of this type. In these places the surface is quite perceptibly sunken and the top soil has a reddish-brown color and an ashy consistency. In other small spots alkali salts have formed on the surface. These have an injurious effect on crops when first put in cultivation, but the effect lasts only three or four years. Neither the burned areas nor the alkali spots are of sufficient extent to be shown on a map of the scale used in this survey.

Peat occurs only in three areas within the region of morainic topography. The largest, covering 350 to 400 acres, occurs in Grassy Lake; the second largest, containing about 80 acres, lies just east of the Chicago, Milwaukee & St. Paul Railroad, about 2 miles southeast of Juniata; and the smallest, comprising approximately 10 acres, is located about 5 miles southwest of Rembrandt.

The areas occupied by this type were formerly sloughs, and drainage is wholly dependent on systems of tile drains eventually having an outlet in open ditches. Where properly installed these systems take care of both surface drainage and underdrainage.

Practically all the areas mapped as typical peat are in cultivation. Corn is almost the only crop grown. A very small area is devoted to oats. The average yield of corn when allowed to mature is 25 to 50 bushels per acre. As this type is probably more susceptible to frost than any other soil in the country, much of the corn is cut early for fodder or silage. The soil is handled in the same manner as the Webster silt loam and muck. The selling price of the land ranges from $150 to $200 an acre.

Means suggested for the improvement of the Webster silt loam and muck are equally applicable to peat. In addition, manure should be applied to burned-out spots to replenish the lost organic matter, and where alkali sports are troublesome the soil should be cultivated as frequently as possible to promote leaching by rains.

The small areas mapped as peat, but distinguished with swamp symbols, comprise undrained basins or sloughs which are covered with water the greater part of the time. These areas were inundated at the time of the present survey, and in most parts inaccessible. Where they could be examined the surface soil beneath the water was a spongy muck or peat

extending to a depth of 10 to 12 inches, underlain by the subsoil characteristic of muck and peat. Probably all of this land will be reached by artificial drainage systems in the near future and put in cultivation. Many of the small areas doubtless have been drained and put in cultivation since the time of the survey. It is possible that they may prove to include areas of Webster silt loam and to a lesser extent Webster silty clay loam. So far as known all the areas can eventually be drained.

Mitchell County, Iowa.

Mitchell County is the fourth county from the east in the northern tier of counties of Iowa. It is bounded on the north by Mower County, Minn., on the east by Howard County, Iowa, on the south by Floyd County, and on the west by Cerro Gordo and Worth Counties. The county is rectangular in outline, and is about 23¼ miles long from east to west, and 20 miles wide from north to south. It has a total area of 467 square miles, or 298,880 acres.

Only a few acres of muck of sufficient extent to be mapped satisfactorily are found in the county. The largest area is about 7 miles west of Osage, on a branch of Rock Creek. The material consists of a stratum of black, finely divided vegetable remains, varying in thickness from a few inches to several feet. It is underlain by clay or sandy clay. The lime rock occurs in a few places at comparatively shallow depth and possibly is one cause of the obstructed drainage to which the areas of muck owe their origin. Smaller areas occur on upper Rock Creek and in various places on the upland in other parts of the county. In all instances the depth of the black, carbonaceous material is greater near the center of the area, but usually does not exceed 3 or 4 feet.

The areas in the northwestern corner of the county near the Cedar River occur on a slightly elevated part of the bottom land. The material consists of several feet of nearly pure muck, resting upon calcareous clay. Small patches, rarely exceeding a few acres, are found in all the river valleys. These are of little economic value. There is also considerable muck land in the poorly drained areas of the Clyde silt loam.

Shallow muck underlain by clay has proved in the Eastern States more satisfactory under tillage than similar deposits resting upon sand. In the former more or less earthy material is mixed with the vegetable remains, and the potash supply is doubtless better than where sand constitutes the substratum. Drainage is the main factor in determining the agricultural value of mucky soils, and the high moisture-retaining power of the material sometimes renders satisfactory drainage

too expensive where ordinary crops are to be grown. Corn on the muck areas is generally of poor quality and oats are difficult to harvest on account of their tendency to lodge. Good yields of wheat and barley are reported in some areas. The safest use of muck seems to be for bluegrass and timothy, both of which are adapted to such land without a thorough reclamation, as is necessary for grain or truck crops.

St. Martin Parish, Louisiana.

St. Martin Parish is situated in the southern part of Louisiana, about 90 miles west of New Orleans and about 40 miles north of the Gulf of Mexico. The southeastern part of the parish is separated from the main portion by a strip of Iberia Parish about 10 miles wide. The main part of the parish is bounded on the north by St. Landry Parish, on the east by Iverville Parish, on the south by Iberia Parish, and on the west by Lafayette Parish. The detached portion lies between Assumption and St. Mary Parishes. In a number of places the parish line could not be definitely located. The survey comprises an area of 692 square miles, or 442,880 acres.

The material mapped as peat consists of brown, fibrous, or felty, partially decomposed vegetable matter, ranging in depth from a few inches to 3 feet or more. Usually it contains a layer of mucky clay, which is black in the upper part and bluish or mottled blue and drab in the lower part.

Peat occurs in the southeastern part of the parish along the shores of Spanish Lake or Lake Tasse, and a few small areas west of St. Martinville. It is always saturated, except in prolonged dry spells, when the upper 5 or 6 inches may be dry.

The material is derived from an accumulation of organic matter consisting principally of water hyacinths, fresh-water mosses, and water-loving grasses. None of the peat is forested. It is used as a range for cattle.

Calhoun County, Michigan.

Calhoun County is situated in the central-southern part of Michigan, about 85 miles west of Detroit and 150 miles northeast of Chicago. It is bounded on the north by Barry and Easton Counties, on the east by Jackson County, on the south by Branch and Hillsdale Counties, and on the west by Kalamazoo County. It has an area of 693 square miles, or 443,520 acres.

Muck and peat include soils composed largely of organic matter. Peat is composed almost entirely of vegetable mat-

ter, consisting of roots and leaves of water-loving plants and trees in various stages of decomposition. The first stage in the formation of the deposit consists of raw, brown peat, fibrous in structure, and held together in felty masses in which the plant forms are still recognizable. The soil below this vegetation is dark in color, occasionally being black. It is generally saturated with water at no great depth below the surface, and is nearly or quite devoid of visible mineral matter. It extends to depths ranging from a few feet to 20 feet or more. Brown peaty soil of felty, fibrous nature can rarely be used for crop production, on account of its unfavorable physican condition. Huckleberry and tamarack are a common growth on such land. As the mineral or earthy matter increases and traces of the original vegetation begin to disappear, the material assumes a finer texture and darker color, finally becoming a muck soil.

Muck consists of an accumulation of vegetable remains in a more advanced state of decay than peat, mixed with variable, though usually small quantities of clay, sand, and silt carried into the depressions by wash from higher surrounding areas or by the wind. Muck is dark brown to black and mellow. The deposits vary in depth from a few inches to 10 feet or more. Typical muck is quite uniform in color, texture and structure to a depth of 30 inches or more. In some places sufficient earthy matter is present to give it a dark-gray or gray color and a firmer structure.

The underlying material of muck and peat varies from a gray sand or sand to a gravel to a gray or drab silty clay. The agricultural value of the land depends largely upon the character of the subsoil material and its depths below the surface. The greater part of the muck and peat land is underlain by sandy and gravelly loam or clay. The substratum consists of gray, stratified gravel, sand, and clay, often showing a strong lime reaction. Layers of bog lime or marl occasionally occur in the subsoil, but usually not in sufficient quantity to affect the upper soil.

Muck and peat occur in all parts of the county in areas which range in size from less than 10 acres to several thousand acres. Many of the bodies are too small to be mapped separately. All the areas occupy naturally poorly drained depressions, in which swampy conditions have been formed in glacial depressions since the last ice sheet withdrew. The areas support a luxuriant growth of tamarack, poplar, willow, reeds, rushes, flags, mosses, sedges, and huckleberry, with elm, soft maple, and other trees in the better drained places.

Areas of muck and peat have a flat surface and often lack

outlets, and it is sometimes difficult to provide good drainage, which is necessary to fit them for cultivation. Areas in which the subsoil consists of sand are considered less desirable than those having a heavier subsoil. In such areas the underdrainage is likely to be excessive following the installation of tile. A gravelly and sandy clay subsoil is considered the best subsoil.

A number of county drains have been constructed through muck and peat areas, but only a comparatively small proportion of the land is under cultivation. Much of it has been cleared of trees and bushes and is used for summer pasture. Nearly all the general farm crops succeed on good muck land. The chief crops in this county are corn and hay. Small grains grow well, but have a tendency to produce a rank growth of straw and are likely to lodge. This is especially true of wheat. Certain varieties of oats and barley succeed, but probably the best crop of all is hay. Alsike and timothy are successful crops. They are usually sown together, although timothy generally does well alone. Yields of 2 to 3 tons of hay per acre are common on properly drained land. Corn and certain other crops do not do well on newly broken areas. Some farmers use the land for hay or pasture the first few years. Quite often the difficulty in growing crops is overcome by applying stable manure and practicing thorough cultivation. Corn in new areas is often brown in color and stunted. The yields on old fields ordinarily range from 35 to 55 bushels per acre, and yields of 60 or even 75 bushels per acre have been obtained under particularly favorable conditions. Oats yield 20 to 35 bushels, and occasionally 40 to 55 bushels per acre.

This soil is well adapted to many special crops, including celery, onions, cabbage, lettuce, carrots, parsnips, horse-radish, spinach, tomatoes, sugar beets, and peppermint. Peppermint, however, has not proved so profitable as in certain other parts of Michigan, and the crop is grown in only a small way. Onions have, as a rule, proved very profitable throughout the county. Near Battle Creek a considerable acreage of muck is profitably devoted to truck crops. Huckleberries grow wild in the peat bogs, and are a source of income in many places.

A considerable number of farmers formerly burned over their muck and peat lands, but this practice is now less common and is considered injurious. Fertilizers are used on muck land to some extent and many farmers apply barnyard manure with good results. The Michigan Agricultural Experiment Station has published information regarding the fertilizer requirements of peat and muck lands. The interested reader should consult this report.

A conservative estimate places the value of undrained muck and peat land at $15 to $30 an acre. Some acres sell for higher prices, depending on the natural drainage conditions, the location, possibilities of future development, the pasturage, and other factors. Land drained by main ditches sells for $40 to $70 an acre, depending largely upon the drainage. Tile-drained lands are valued at higher prices. Some desirable drained muck land in small areas near Battle Creek is held at $400 or $500 an acre.

The first step necessary in the improvement of muck and peat land is proper drainage. It probably is best to use the open ditches at first, and to install tile drains later, after the soil settles and becomes compact. Rolling and compressing of the seed beds are necessary for the best results. Crops do best in the areas of black deposits, with a relatively large proportion of earthy or mineral materials and of close texture, such as exist where the organic material has reached an advanced stage of decomposition.

Anoka County, Minnesota.

Anoka County is situated in the southeastern part of Minnesota, a few miles north of Minneapolis and St. Paul. It is bounded on the north by Isanti County, on the east by Chicago and Washington Counties, on the south by Ramsey and Hennepin Counties, and on the west by Sherburne County. The Mississippi River flows between Anoka and Hennepin Counties. The area included is 431 square miles, or 275,840 acres.

To a depth of 10 to 12 inches the typical peat consists of a brown to black, spongy, more or less resistant mass of partly decayed roots, stems, and other vegetable remains, intermixed with more finely divided and more thoroughly decomposed peaty matter. The underlying material to a depth of 3 to 10 feet or more is uniformly more dark in color, and is composed of more finely divided vegetable matter, resting on a substratum of grayish fine sand, or in places of marl or calcareous deposits.

Peat is an extensive type. It occurs throughout the county in areas ranging in size from a few to several thousand acres. The largest developments are encountered in the eastern half of the county.

The surface of the type is flat or nearly flat. Some areas show a slight slope in the direction of the natural drainage. The peat is prevailingly poorly drained. Considerable ditching has been done, but much systematic work is necessary before the land can be used for farming. Much of the former

ditching was done at the heads of the natural drainage ways, or even above their sources, with the result that the channels were unable to carry off the extra volume of water, and large areas of peat along the lower courses were flooded. Some of this inundated land had formerly been used for hay production. At the present time steps are being taken to deepen the natural drainage channels and to dig large, deep main ditches through the larger peat areas to be connected with laterals. A State law provides that check dams may be placed in ditches when these will cause no injury to adjacent lands. This provision is important to farmers who use marshland areas for growing wire grass, which flourishes only under swampy conditions.

The typical peat supports a varied vegetation. In the wetter open marshes there is a dominant growth of wire grass. The less wet, partly drained open marshes have a cover of various marsh grasses, with "brown top" often the dominant growth. These better drained marshes are locally known as "meadows," and at present they are the source of most of the wild hay produced. About two-thirds to three-fourths of the peat area is open marsh. Much of the remainder has a mixed cover of native grasses, with swamp willow, alder and other brushy shrubs, and a second growth of poplar on burnt-over patches. In some places there is a rather dense growth consisting principally of tamarack trees ranging from 3 to 6 inches in diameter, with a scattering undergrowth of grass and brush. The area forested with tamarack at one time yielded considerable timber for railroad ties and cordwood.

Most of the type at present may be used, and much of it is used, as pasture land. A considerable proportion is used for the cutting of wire grass for the manufacture of matting, and a large total area is cut over for hay. Cultivation is limited to the growing of corn, tame grasses, and some other crops in an experimental way, the total acreage of deep peat brought under the plow to date amounting to less than 200 acres. Wild hay is cut in August and September. Under average conditions at this season of the year even areas ordinarily wet are sufficiently dry to permit the use of horses, shod with bog shoes, in the cutting of wire hay, the spongy surface material being sufficiently firm to carry the team, even though the peaty material beneath is wet and plastic.

The yields of wild hay on the typical peat range from about three-fourths to 1½ tons per acre. Any extensive utilization of peat for the growing of cultivated crops is dependent on adequate drainage. The land is ordinarily most completely drained in the fall, and plowing and seed-bed prep-

ation could well be done during that season. When the land has been sufficiently drained, the use of heavy teams in cutting hay and the tramping of livestock in pasturing are beneficial in breaking down and compacting the material. In some other counties heavy traction engines are employed on peat to compress the mass. Where there is an abundance of tough roots and brush, burning has been found beneficial. This must be done at a time when only the surface, 3 or 4 inches, is dry enough to burn, as otherwise fires may get beyond control. According to the limited investigation that has been made, phosphatic preparations and barnyard manure are the best fertilizers to use in farming the peat of Anoka county.

Prices for land composed of the typical peat range from less than $10 an acre to as much as $30 an acre. There are no farmsteads on this land, the buildings being placed on adjoining upland soils.

The peat, sandy-subsoil phase, consists of black peat, containing a small percentage of sand, to a depth of 10 to 18 inches, underlain by a grayish, fine sandy subsoil which usually rests upon a sandy substratum. The peaty accumulation ranges in thickness from a deep deposit in some places to a very thin layer next to the upland. The surface material ranges considerably in texture, owing to various admixtures of fine sand. With good drainage and continued cultivation the peaty material would gradually be worked into the underlying sand, giving rise to a dark-gray or black sandy surface soil.

The peat, sandy-subsoil phase, is not extensive. A few areas lie in the east-central part of the county, where they are associated with larger areas of typical peat and are either surrounded by or adjacent to the Merrimac loamy fine sand. As in the case of the typical peat, the surface of this soil is nearly level and the drainage prevailing poor. The phase in some places occurs on low shelves next to the uplands, and here has slightly better natural drainage. The installation of ditches in the areas of the deeper, typical peat would materially improve the drainage of the sandy-subsoil phase.

The peat, sandy-subsoil phase, supports a native growth similar to that on the typical peat, except that tamarack and wire grass are almost entirely lacking. The phase is used to a considerable extent for pastures and the cutting of wild hay. Corn and tame grasses are grown to a small extent. The yields of wild hay range from three-fourths to 1½ tons per acre. Corn, tame grasses, and other crops give promise of good yields after the land has been well drained.

This soil where under cultivation may safely be plowed in

the fall and prepared long in advance of planting. Harrowing or otherwise loosening the surface soil in the spring aids in warming up the seed bed.

Prices of peat, sandy-subsoil phase, have about the same range as for the typical peat, from less than \$10 to about \$30 an acre. The phase is usually sold in conjunction with upland soils, and the price depends largely on the state of improvement, the transportation and market facilities, and the nearness to high-priced lands.

The peat, heavy-subsoil phase, consists of black sandy peat or muck 10 to 18 inches deep, underlain by a grayish, clayey to fine sandy clay subsoil, which rests upon either a clayey or a fine sandy substratum. As in the case of the sandy-subsoil phase, the peaty accumulation is deep in some small areas and very thin in some places next to the uplands. The surface material also varies widely in texture, owing to various admixtures of fine sand and clay. Under good drainage conditions and with continued cultivation the peaty material would gradually disappear, leaving a black, mucky, sandy or clayey material.

The peat, heavy-subsoil phase, occurs in association with upland soils of clayey texture or underlain by clayey subsoils, such as the Miami and Gloucester soils. It is of small extent, occurring in a few areas in the southeastern and northwestern parts of the county. The surface is nearly level, with, in places, a slight slope in the direction of natural drainage.

A shelflike position of some areas occurs as in the sandy-subsoil phase. Drainage is slightly better here, but as a whole the phase is poorly drained.

The peat, heavy-subsoil phase, supports a native growth similar to that on the typical peat, except that there is practically no tamarack or wire grass. Some of the phase is being drained. It is used to a considerable extent as pasture and the cutting of wild hay. A small total area is used in growing corn and tame grasses. The yields of wild hay probably average somewhat higher than on the sandy-subsoil phase. When drained it will be more productive and more durable. The land ranges in price from \$10 to \$30 an acre.

Mercer County, Pennsylvania.

Mercer County, Pa., is situated in the nowthwestern part of the State, along the Ohio line, almost midway between Pittsburg and Erie. It is bounded on the north by Crawford County on the east by Venango County, and on the south by Butler and Lawrence Counties. It contains 700 square miles. or 448,000 acres.

Muck and peat are organic soils formed by the accumulation and decay of the remains of water-loving plants. The accumulation has been favored by the rank growth of vegetation in wet, swampy places, and by those processes of decay that are evolved under conditions of saturation.

The formation of muck and peat has been going on for ages and is still in progress. With the organic matter, which is in varying stages of decomposition, there are admixed small quantities of mineral particles which have been incorporated from time to time, usually in the form of water-deposited sediments.

As a result of these different factors, the organic deposits are not uniform in texture, and muck and peat are intermingled. Where the process of decay has not reached an advanced stage and the organic remains retain a rather distinct fibrous or cellular structure, the material is true peat. This is usually brown or dark brown in color, though in some places almost black. In the areas classed as muck the material has undergone more through disintegration, and has attained such an advanced stage of decay as to become a black, spongy mass with little if any trace of the original structure of plant tissues. The depth of the organic deposits also varies greatly. In a few places they are only 8 to 12 inches deep, but ordinarily the depth is at least 2 feet, and in some place 20 feet or more. Where the organic deposit is less than 3 feet deep the underlying soil is a rather light gray, sticky, sandy clay or sandy loam, or a bluish-gray to drab, heavy clay.

Muck and Peat areas form the filled-in beds of old lakes and ponds. They also occur in swampy depressions along streams. The largest areas occur in the vicinity of Valcourt and Grove City, 3 miles north of Mercer, 3 miles southeast of Greenfield, southeast of Clarks Mills, northwest of White School, and in the Cranberry Swamp. The areas are low and level and in nature so wet and swampy that they can scarcely be crossed. Water generally covers large areas during most part of the year. The characteristic growth consists of cattails, and water-loving grasses and bushes, but some areas of shallow muck have a heavy stand of pine and hemlock.

Muck is usually preferred to peat for agriculture, because it is more compact. Both types can be used to a certain extent for trucking, but peat, because of its light, spongy structure, affords rather poor support for crops attaining much height.

None of the large tracts of muck and peat have been reclaimed. Small areas have been drained and are used for growing truck, as near Grove City. Some alsike and timothy are

grown on one acre. Many of these swampy areas require rather extensive drainage and clearing operations, but where they lie fairly close to markets the initial cost, though considerable, would be justified by their value for trucking. Celery, onions, cabbage, lettuce, spinach, beets, turnips and potatoes can be profitably grown. In certain sections of the United States corn, buckwheat, and hay are grown on muck soils. It is not uncommon to find that after freshly cleared areas of muck have been cropped for about three years they begin to show signs of lessening productiveness. In such cases it has been shown the element most needed is usually potash, though phosphoric acid is required to a less extent.

The Amisk-Athapapuskow Lake District, Canada.

The Amisk-Athapapuskow Lake area is situated 50 miles north of Saskatchewan River and is crossed by the boundary line between Manitoba and Saskatchewan. It lies along the edge of a part of the Canadian Pre-Cambrian shield and about one-half of it is underlain by Palaeozoic rocks. The general elevation is in the neighborhood of 1,000 feet above sea-level. The southern part of the district, which is underlain by flat-lying Palaeozoic rocks, is very level, any irregularities that may have existed having been to a great extent obliterated by a fairly thick deposit of lake clays.

Recent deposits are represented chiefly by peat and in a few places by very local deposits of alluvium along river valleys and by beach deposits along lake shores. At the mouths of some streams deltas are forming, but these are small because practically all the rivers and streams of this area have clear water. In most cases the delta deposits are largely composed of vegetable material and the woody particles obtained from the cutting of peat banks by the streams in flood time. Along lake shores the waves have cut cliffs in the drift and alongshore currents have transported the material removed to form sand pits, usually close to the source of the supply.

Peat is the most important of the recent deposits. It covers to a considerable depth the greater part of the area underlain by the lake clays and is found in the valleys between the rocky ridges of that part of the country which has little drift covering. In poorly drained areas organic matter is preserved from complete decomposition and accumulates year after year as the various swamp plants, mainly sphagnum moss, grow upward and the lower parts die and are added to the mass. These flat bogs are commonly called muskegs.*

*From a Chippewa word meaning a grassy bog.

In a practical way muskegs may be classified (1) as those in which the peat rests directly upon the clay subsoil or upon rock and so have a soft but still fairly firm surface, and (2) those in which the peat is separated from the solid underlying formation by a greater or less depth of very thin ooze. These latter form the "floating" bogs that make travel across much of the clay-covered district so difficult during the summer months. In muskegs of the latter type the matted roots of the sphagnum moss and other water-loving plants form a surface sufficiently tough to sustain a man's weight, but sometimes flexible enough to move up and down in wave-like undulations under each step, and so are given the name of quaking-bogs. A slight weight presses down the surface below water-level. The drainage of such areas is seldom by means of regular streams, but rather by a sort of mass flow of the water without any well-marked channel. Some of these floating bogs seem to be the result of the outgrowing of shore bogs in shallow, muddy lakes until the open water is completely covered. This probably could only occur after a lake had practically been filled up by vegetable ooze.

If the briquetting of peat becomes a commercial possibility the great peat bogs of this country should be valuable fuel resources. No careful estimate of the average thickness of peat over the clay subsoil has been made, but in some places it is considrable.

DRYING PEAT.

H. H. Hindshaw, (U. S. P. 1,334,492).

Peat is conveyed through a chamber, partly cylindrical and partly conical, by means of a screw, which breaks up the peat in the cylindrical part and compresses it in the conical part. The peat then passes to another chamber, where it is subjected to similar treatment. but under a vacuum to remove the air that was released from the air cells by the first treatment.

MUCK SHOES FOR HORSES.

William J. Curry.

This invention claims a device which can be readily attached or detached to horses, and prevents the horse from sinking when passing over peaty land; provision is also made for attaching calks thereto. The locking device employed is

resilient and possibility of the accidental loss of a shoe is reduced to a minimum.

The shoe consists of a flat plate, which is deflected upward at its forward end, the corners being rounded. Adjacent to the forward end is a medially arranged accurate toe plate. On the bottom of the plate are lugs.

The toe plate is arranged to co-act with the toe of a horseshoe, a heel plate co-acts with one heel portion of a shoe, and a lever carried by the muck shoe co-acts with the other heel portion of the horseshoe. (U. S. Pat. 1,343,456.)

DRYING PEAT.

C. Bouillon. (Br. Pat. 140,112.)

Peat, preferably in a finely divided and rained condition, is mixed with a body capable of coagulating blood, and the fibers and cells are then separated by known methods of filtration, drying and decantation. Solutions of calcium chloride and perchloride of iron are stated to be suitable agents.

PEAT TREATMENT.

R. Gruhl (Ger. Pat. 310,111).

Peat is rendered water-resistant by treatment with hydrochloric or nitric acid, chlorine, or acid salts of mineral acids, or by treatment first with chlorine and then with nitric or hydrochloric acid, or with a mixture of these acids. Moulded peat may be treated with dilute nitric acid and then heated, either with or without pressure. The gelatinous constituents of the peat are changed into substances which do not swell in water and are easily washed out; the washed peat may be moulded with or without pressure. After drying the treated peat has completely lost its swelling power and almost completely its water-absorbing power.

CARBONIZING OVEN FOR PEAT.

R. Schroeter.

A horizontal carbonizing chamber, heated from below, communicates with an adjacent shaft which extends vertically downwards, and in which the carbonized peat is saturated with tar and gaseous products carried by the gases passing down the shaft, so that little besides water vapor escapes into the chimney. (Ger. Pat. 316,213.)

PEAT FIBER SPINNING.

H. Deelen. (Ger. Pat. 316,511.)

This process claims to convert short, brittle peat moss fiber into a condition suitable for spinning. Peat or peat moss, previously freed from impurities, is treated with a dilute solution of soap or emulsion of fat in such a way that the individual fibers are penetrated by the fatty matter, and the production of a pasty, sticky mass is avoided. The impregnation may take place during the separation of the impurities by shaking or other mechanical treatment of the fibrous material, or else after it has been washed. Yarns can be spun from the treated peat or peat moss, which do not shrink under the influence of air and moisture, and which are extremely soft and pliable, suitable for weaving in conjunction with stronger materials, such as wool, cotton, or jute.

GASIFYING PEAT.

Elektro-Osmose A.-G. (Ger. Pat. 316,651.)

The peat is dried by hot air, the air which has become laden with moisture in its passage through the drying room being discharged into the gas producer. In this way the moisture contained in the drying air is utilized for the gasification, and in the production of "semi-water-gas" the quantity of steam required may be reduced.

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Founded at the Jamestown Exposition on October 23rd, 1907. Its object is to further the interest in the uses and application of peat for industrial and economic purposes.

PUBLICATIONS.

The Society holds one general meeting per year, and publishes a Journal quarterly, which is sent to all members in good standing. The journal includes the proceedings of the meetings, original papers on practical experience, etc., also abstracts on all contemporary literature and patents, thus all the latest agricultural uses, fertilizer purposes, drainage, fuel, uses, technical uses, etc.

SOME ECONOMICAL POINTS OF INTEREST.

Prof. Chas. A. Davis, U. S. Bureau of Mines, estimated that there are about 12,000 sq. miles of workable peat beds in the United States, outside of the large number of beds very advantageously adapted for agricultural purposes, etc. He gave as a conservative estimate a yield of 200 tons dried peat per acre foot.

Canada has at least 37,000 sq. miles of known peat deposits.

About ten million tons of peat are used in Europe each year.

GENERAL INFORMATION AND INQUIRIES.

All members have the privilege of making inquiries regarding general information about peat and its uses, by addressing the Secretary of the Society.

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